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The Modern Outback

Nature, people and the future of remote Australia

Contents

The Pew Charitable Trusts

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Pew's work in Australia aims to secure protection for all areas of high conservation value in the Australian Outback. In addition, we pursue effective management of adjacent areas that is compatible with the conservation of the whole landscape.

This publication is the first in The Outback Papers series, which Pew is commissioning to document one of the last extensive natural regions left on our planet, its value, the threats to its health and the opportunities available to create a modern Outback that values its nature and sustains its people.

Authors

The Modern Outback: Nature, people, and the future of remote Australia, was authored by **Professor John Woinarski** from Charles Darwin University's Research Institute for the Environment and Livelihoods; **Dr Barry Traill**, Director of The Pew Charitable Trusts' Outback Australia Program; and science editor, writer and policy adviser **Dr Carol Booth**.

External reviewers

The research benefited from the insights and expertise of three external reviewers: Dr Steve Morton, Executive Chair of Environment and Natural Resources, Commonwealth Scientific and Industrial Research Organisation; Harvey Locke, Yellowstone to Yukon Conservation Initiative; and Dr Guy Fitzhardinge, owner of Thring Pastoral Company and Chairman of Karrkad-Kanjdji Trust. These experts provided feedback and guidance at critical stages in the project. Although they have screened the report for accuracy, neither they nor their organisations necessarily endorse its findings or conclusions.

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Cover photo: Hugh Brown

The Australian Outback comprises a rich tapestry of deeply interconnected landscapes that cover more than 70% of the continent. Ochre-coloured soils are a recurring feature across this vast landscape, as shown in this aerial view of a gully system in Western Australia's Pilbara region.

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Laura Land and Sea Ranger Roderick Doughboy and Lyndal Scobell of Cape York Natural Resource Management Ltd discuss land management issues at the Split Rock Escarpment, overlooking the Kennedy Valley, near Laura in Outback Queensland. Land and sea rangers work closely with other land management groups, local authorities, pastoralists, schools and other groups to improve environmental outcomes for their area and raise awareness of the importance of caring for country.

The setting sun highlights a native grasstree and spinifex at Upalinna Lookout in the Flinders Ranges, near Wilpena Pound National Park, South Australia.

1. Introduction

The Outback is the extraordinary heartland of the Australian island-continent. It includes the rugged Kimberley, the wetlands of Kakadu, the rainforests of Cape York Peninsula, the sand dune deserts and iconic Uluru in central Australia, the ephemeral inland river systems and lakes of the Channel Country and Lake Eyre Basin, the Flinders Ranges and the diverse Great Western Woodlands. These are places of exquisite beauty and of wildness, and they give form to much that is both distinctive and characteristic of Australia.

Australians have long celebrated and looked after these individual places. This report seeks to bring more coherence to how we perceive and manage these places by recognising that they all occur within, and are a part of, a vast continuous natural landscape. That connected landscape provides the necessary context, space and resilience for those iconic features to function, but it is also of value itself. That place is the Australian Outback.

Individual components of the Outback may each be distinctively different in appearance and in their plant and animal communities. They occur in different jurisdictions and in different climatic zones. But they all share and contribute to the Outback essence of remoteness, of largely unmodified natural environments, of few people and similar management challenges.

> In an age of diminishing nature, there are few large places left in the world that are still as environmentally intact as the Outback, that offer such a sense of space and allow us to reflect on our fit to the natural world.

The Outback covers nearly 6 million km^2, extending across most of the Australian continent. This report seeks to characterise and understand the nature of this area and to assess its significance. It seeks to recognise the challenges affecting the Outback and to sketch a future for it based on sustaining its natural and cultural values. This attention is warranted because those values may readily be diminished if current and future threats are not addressed and if the Outback's natural values are overlooked, taken for granted or disregarded.

Mount Trafalgar in Prince Regent National Park during the Kimberley wet season in far north Western Australia. The park, one of Australia's most remote wilderness areas, is home to over half the known bird and mammal species in the Kimberley region and more than 500 plant species.

Our focus is on conservation, due to the intrinsic worth of the Outback's biodiversity and because the natural environments of the Outback provide the foundation for all of its enterprises and life. Our focus on conservation is also because we recognise that those natural environments make up the essence of the Outback – the defining quality that makes it special.

From an environmental perspective, the Outback is fundamentally different from the modified landscapes of more densely settled regions of eastern and south-western Australia. In those transformed landscapes, conservation tends to be a more contested issue, for there are competing, economically potent and incompatible land uses. In those areas, conservation is more about seeking to retain or re-connect isolated remnants – the leftovers following two centuries of modification – and the conservation objective now is often reduced to representation of species and habitats, propping up what is left over after the lands and waters have been transformed.

> Taken as whole, the Outback is one of the wildest and most intact places on Earth.

In contrast, in the Outback, the environments remain largely natural and continuous and it is feasible to conserve and manage broad-scale ecological processes rather than simply species and habitats. There are fewer competing land uses and many existing land uses are broadly compatible with conservation. People inhabit many of the Outback's conservation reserves and Indigenous land management activities largely contribute to, and are compatible with, conservation objectives.

While this report is about conservation, our interest is not focused narrowly on national parks and threatened species. It is broader and more inclusive. The Outback is an intricate tapestry, with interconnected threads of people and landscapes. It comprises interdependent ecological and social components. Its people are of, and help make, this landscape and, reciprocally, the land is part of, and helps make, the people. It follows then that the sustainability of its natural systems is indissolubly linked to the sustainability of its socio-economic systems. By national and international standards, remarkably few people live in the Outback, but this is a land subtly ingrained and patterned by people, and of people defined and patterned by Outback nature.

Hence, our objectives are to enhance long-term biodiversity conservation and social and economic wellbeing. For the Australian Outback, this has particular resonance for Indigenous people and communities, who comprise much of its population and culture. For Indigenous people in the Outback, the maintenance of country is not only a profound responsibility but also the wellspring of culture and an opportunity for economic growth and for nurturing governance and capacity.

In part, our perspective here is global. The Outback is of global significance. It supports a rich and distinctive array of plants and animals. It is also one of the world's few remaining extensive, largely natural areas. In an age of diminishing nature, there are few large places left in the world that are still as environmentally intact as the Outback, that offer such a sense of space and allow us to reflect on our fit to the natural world. Such areas are of increasing importance to the wellbeing of the planet and of its peoples.

Taken as whole, the Outback is one of the wildest and most intact places on Earth. If it is managed to remain ecologically healthy it can make a globally significant contribution to securing a safe operating space for humanity by regulating the climate through carbon storage and preserving biodiversity in one of the world's most biologically diverse regions. It can maintain healthy rivers and coastal estuaries free of excess nitrogen to avoid marine dead zones (Rockström *et al*. 2009) and to allow for species to adapt to climate change by moving along unobstructed river gradients and across unfragmented landscapes.

In part, our perspective is national. The Outback comprises almost three-quarters of Australia and it is a core, defining and spiritual component of the nation's self-image. The red sands, brown lands, natural icons and vastness make its people Australian and most differentiate this country from others. Even the twinned symbols on Australia's national coat of arms, the Emu and Red Kangaroo, signal and typify the Outback.

But the Outback's remoteness and sparse population now sit awkwardly in a continent with a population that has become one of the most urbanised in the world. Most of Australia's people, political power and industry hug a narrow strip along the eastern and southern coastline. Those lands have become ordered, transformed, familiar, comfortable and prosperous. Increasingly, they are disconnected from the vast interior and remote north. Our national identity is becoming more cosmopolitan as Australians' concerns are increasingly shaped by city living and their understanding of the bush weakens. Increasingly, few Australians know the Outback well.

So, while the Outback is celebrated in this country's iconography, it is neglected in national, state and territory budgets. It is the core of the continent, but is marginalised economically and politically. Despite its environmental and social coherence across most of a continent, its governance is fragmented. Notwithstanding pockets of productivity that are driving national prosperity, much of the Outback has some of the nation's most impoverished economies and communities..

Through this report, we seek to rekindle our society's affinity with, understanding of and empathy for the Outback environment. Here, we seek not only to explain and re-evaluate the Outback, but also to nurture it, to reconcile the seemingly incompatible notions of its ecological frailty with our image of it as a harsh, rugged and timeless place, and to sketch a future of it that enhances its wonder and its centrality in Australians' lives.

Our perspective is also for those who call the Outback home. For its residents, this is a life-defining concern: how can these lands, and the communities they support, be sustained?

Typical of small populations that are remote from centres of power, many Outback residents feel disenfranchised from the nation's agenda, central narrative and drivers:

'They ask to be treated as though they are a part, an important part, of Australia rather than some forgotten place getting attention from a distant capital when there is a crisis or a mine to be developed.' (Chaney 2012).

The Outback has problems, and these problems are incrementally dulling and diminishing its values. In parts of the Outback, many Indigenous communities suffer social disadvantages and local economies are threadbare and unstable. In some communities, cultural integrity is fraying, knowledge of the distinctive Indigenous languages is fading and connection to land is being eroded. In much of the Outback, regional economies are faltering – young people drift to the cities and their communities' fundamental concerns are neglected, unappreciated or little noticed in the urban engine-rooms of our nation's power.

Across the Outback, the land, its waters and wildlife are faltering under the impact of multiple threats. Some of these threatening factors are high profile and obvious. Others are barely perceptible, but operate pervasively and insidiously. Some native species are now irretrievably lost and others may follow. Ecosystems are becoming less diverse, less productive, less resilient, less special, less capable of sustaining humans. Generally, Australian society little appreciates the extent of such loss: much of it is gradual, remote, inconspicuous, unknown.

It is time to acknowledge and redress these concerns. We seek to identify and face these problems, and to offer solutions. It is in no-one's interest for the Outback to be degraded – for its beauty, cultural significance, communities and unique ecosystems to be lost.

Of course, we recognise that there are already many positive endeavours, much goodwill and hope from existing successes. We relish such achievements. But it is not enough: the magnitude of the problems and the rate of loss exceed the current response and too many of the existing remedial actions are piecemeal and transient. More coherent, strategic and longer-term responses are required.

Indigenous Ranger Benny Jabbalari conducts a controlled burn in spinifex country in the Tanami Desert, Northern Territory. The Tanami comes under two Indigenous Protected Areas, with rangers working to manage threats such as wildfires, weeds and feral animals.

> It is in no-one's interest for the Outback to be degraded – for its beauty, cultural significance, communities and unique ecosystems to be lost.

The Outback is changing. In part, this is due to diminution and loss as some communities wither, cultural continuity cracks, watercourses are degraded and weeds and pests reshape the landscapes. But also, new technology and approaches have come to the Outback. In many areas, the mining boom is changing regional economies, social structures and nature itself. The vast landscape is increasingly understood and managed through the Internet, satellite imagery and GPS units. In some areas, the carbon market has become more lucrative than traditional pastoralism. In an impressive recent development, flourishing Aboriginal ranger groups have brought new means and purpose to remote communities. With skill, vision and coherence, there is hope that this transformation can sustain and re-mould much of the value of the old Outback, successfully manage new and emerging threats, shed much of the malaise of the old Outback, and deliver a vibrant 'modern Outback' that cherishes and protects its essence and values.

> We want, and nature needs, people in this landscape.

In this publication, our narrative involves several intertwined themes. We consider the natural values of Outback Australia and their national and global significance, and note that these environmental values underpin Outback life and livelihoods. We then explain how the Outback functions ecologically. Following from this we assess the current threats to the Outback. We focus particularly on threats to conservation and the need to support people remaining on country to ensure its good management. Finally, we provide an overview of potential development that would be compatible with maintaining the nature of the Outback in its many and diverse component regions. We argue that retaining an extensive, intact and functional natural Outback environment should be a high priority for Australia, in keeping with its outstanding international value. Such an objective is also a necessary underpinning for a sustainable and socially just Outback economy. It contributes to the environmental, social and economic wellbeing of Australia as a whole. We argue that these objectives will not be realised by default or by maintaining current governance and management practices.

The authors of this report care about and are attracted to the Outback because we see it as an important part of the rapidly diminishing treasury of the world's great and large natural areas. We want this global significance to be more broadly recognised, celebrated and safeguarded. Our perception and vision are not of the Outback as a pristine and unpopulated place, but rather as a landscape enlivened by culture and giving form and essence to that culture. We want, and nature needs, people in this landscape, and strong regional economies. These are necessary components of the Outback's future, and that future depends on maintaining and reinforcing the strongly interdependent economic, social and environmental sustainability across remote Australia.

This report – the first in The Outback Papers series – provides an invitation to such consideration. It cannot provide a comprehensive blueprint for the Outback's future management, for that requires much further detail and far more input from those who live in, use or are concerned about this place. However, it does represent the sounding of an alarm for all Australians. The social and natural integrity of the Outback is under threat. The future of its people and its nature now depends on critical choices that need to be made in coming years about the use and management of land in remote Australia.

Following the broad overview presented in this report, further studies in The Outback Papers series will provide more detailed accounts of particular Outback features and challenges, such as the management of fire, broad-scale conservation management and mining.

Through this process, we hope to convey a sense of the Outback's identity and value, the way it works, how important it is, the problems it faces and the opportunities to plan for a future that sustains the living heart of Australia, that enriches us all.

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2. What is the Outback?

The word 'Outback' was coined by 19th century settlers as a contraction of the phrase 'out in the back settlements.' It is also often referred to as the Inland, remote Australia, the Never Never, or 'the back of beyond.'

2.1. Where is the Outback?

The Australian Outback is not usually given a precise geographical descriptor. It is not regularly depicted on maps. To date, the word has seemed to be deliberately, and perhaps delightfully, vague. In Australian myth it is somewhere else, further out, not here.

But the Outback does have a tangible reality and can be defined and mapped. And such a definition provides a useful framework for assessing its value and management. Broadly, the features of the Outback are its remoteness from population centres (Figure 1), its largely unmodified natural setting, the infertility of its soils and its sparse population.

> It is a vast land. But it is also profoundly interconnected.

Based on these defining features, we map the area we consider as the Australian Outback in Figure 2 and define it in more detail in Insight 1. Its total area of 5.6 million km^2 comprises 73% of the continent. It is broadly comparable to the loosely defined 'remote Australia' or the 'Rangelands' of Australia (Bastin and ACRIS Management Committee members 2008), but of the Rangelands area we exclude the partially cleared and highly altered regions of much of western New South Wales and central Queensland because they are inconsistent with one of the key defining features of the Outback, its largely natural condition (Booth and Traill 2008).

The remoteness of, and low population density in, the Outback are no accident: these characteristics are largely dictated by the environment. Although Australia is a relatively infertile continent, this trait is accentuated in the Outback. The Outback's infertility and its climate dictate that it has markedly lower net primary productivity – effectively, the rate and amount of plant growth – than Australia's settled temperate areas (Figure 3). The Outback is infertile, so the population is small and scattered and communities are remote, so its environments have remained relatively intact (Figure 4). Also, because the land has had limited potential for productive commercial enterprise, a relatively large amount has remained under Indigenous management and, more recently, formal ownership.

Insight 1

The Outback defined: lines on a map

As far as we are aware, the Outback has never before been explicitly mapped. For this report, we draw lines on a map of Australia to clarify the area that we consider as Outback. Those lines are best considered as broad-brushed.

The south-eastern boundary of the Outback as defined here is the Murray–Darling catchment: the Outback is inland of the substantially modified Murray–Darling catchment. In the north-east, the boundary is defined by bioregions, with all of the Cape York Peninsula and Einasleigh Uplands bioregions included as Outback, but the Wet Tropics excluded. Between the Murray–Darling Basin border and the Einasleigh Uplands bioregion, the boundary follows the eastern edge of the Lake Eyre Basin.

In southern South Australia, the Outback boundary is drawn to exclude the substantially cleared Eyre Yorke Block bioregion but include the Broken Hill Complex bioregion, and the boundary is taken to extend through the Flinders Lofty Block bioregion to join these defined edges.

In south-western Australia, the Outback boundary is drawn to largely exclude the extensively cleared wheatbelt areas and generally follows bioregional boundaries – with the exclusion of all of the Geraldton Sandplains, Avon Wheatbelt and Esperance Plains bioregions – but with a border dissecting the Mallee bioregion following the western and southern edge of the Great Western Woodlands.

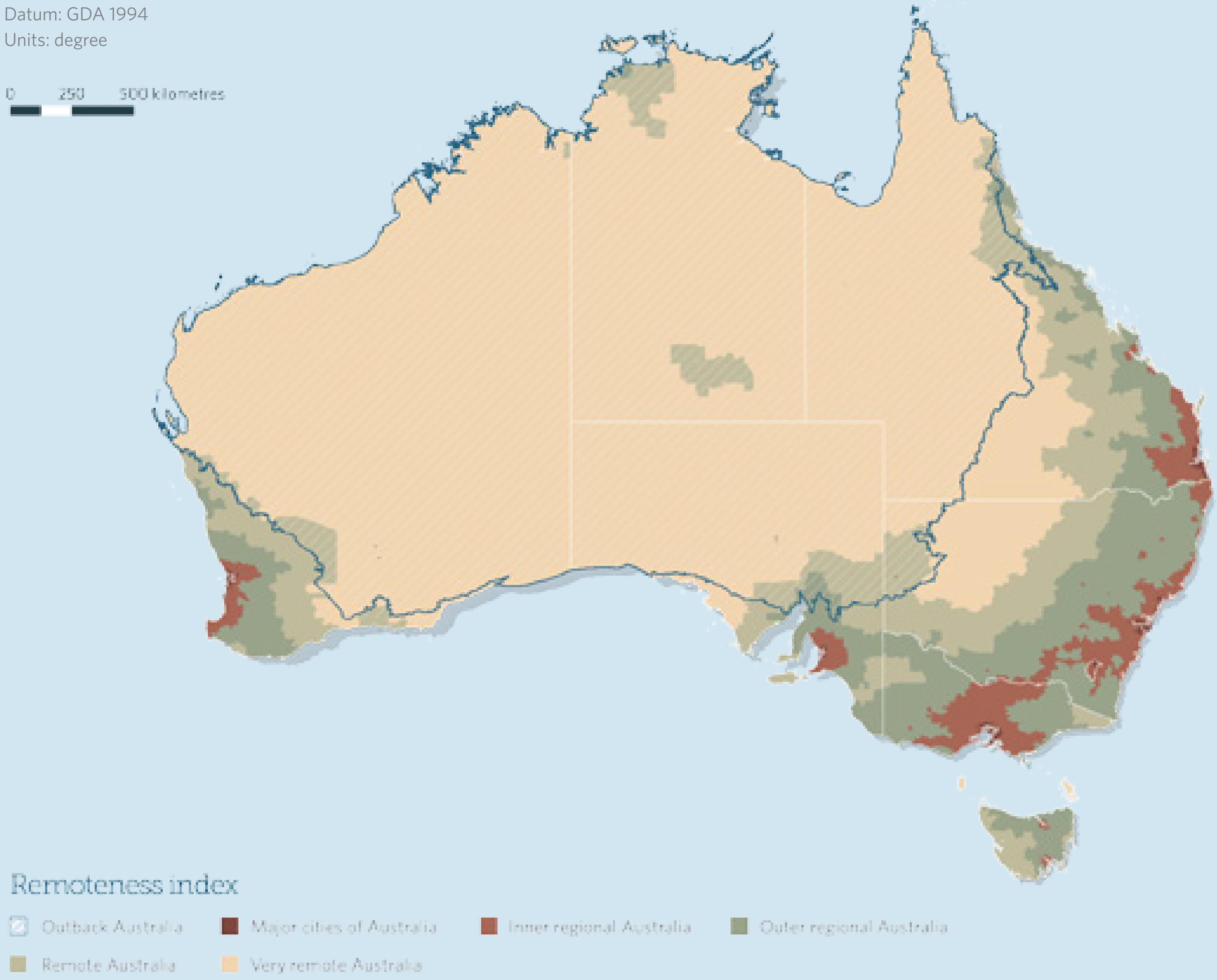
The Outback is taken to extend to the coast (and continental islands, such as Groote Eylandt) from the Shark Bay area across the north-western and northern coasts to Cooktown in north-eastern Australia.

Outback landscapes cover more than 70% of the Australian continental landmass. They also meet the ocean along large sections of the southern, western and northern coastline, as shown in the dramatic red cliffs at Barred Creek, Dampier Peninsula, Kimberley region, Western Australia. In addition to the coast's unusual deep red cliffs, its sands support a distinctive *Acacia*-dominated ('pindan') low woodland.

Figure 1

Remoteness in Australia, Based on a Set of Distances to Services and Population Centres of Varying Size

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: degree



Source: Australian Statistical Geography Standard: Volume 5 – Remoteness Structure*

*Note that full source details for all maps and diagrams are compiled in Appendix 2.

Figure design by The Pew Charitable Trusts

Figure 2

Geographic Definition of the Australian Outback as Used in This Report

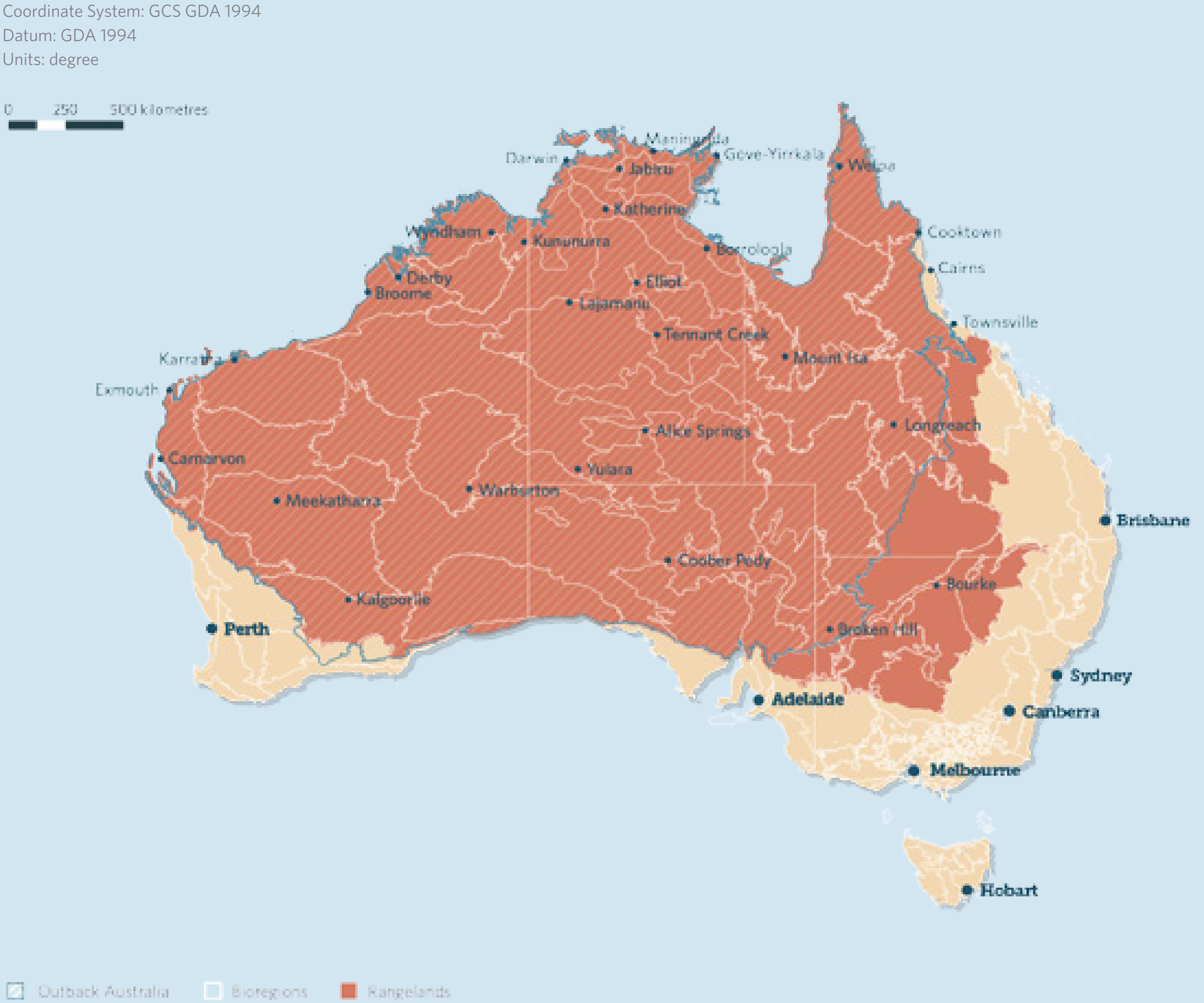


Figure design by The Pew Charitable Trusts

Figure 3

Mean Annual Net Primary Productivity Across Australia

Note the relatively good fit to the Outback area (tonnes of carbon per hectare per year)

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: degree

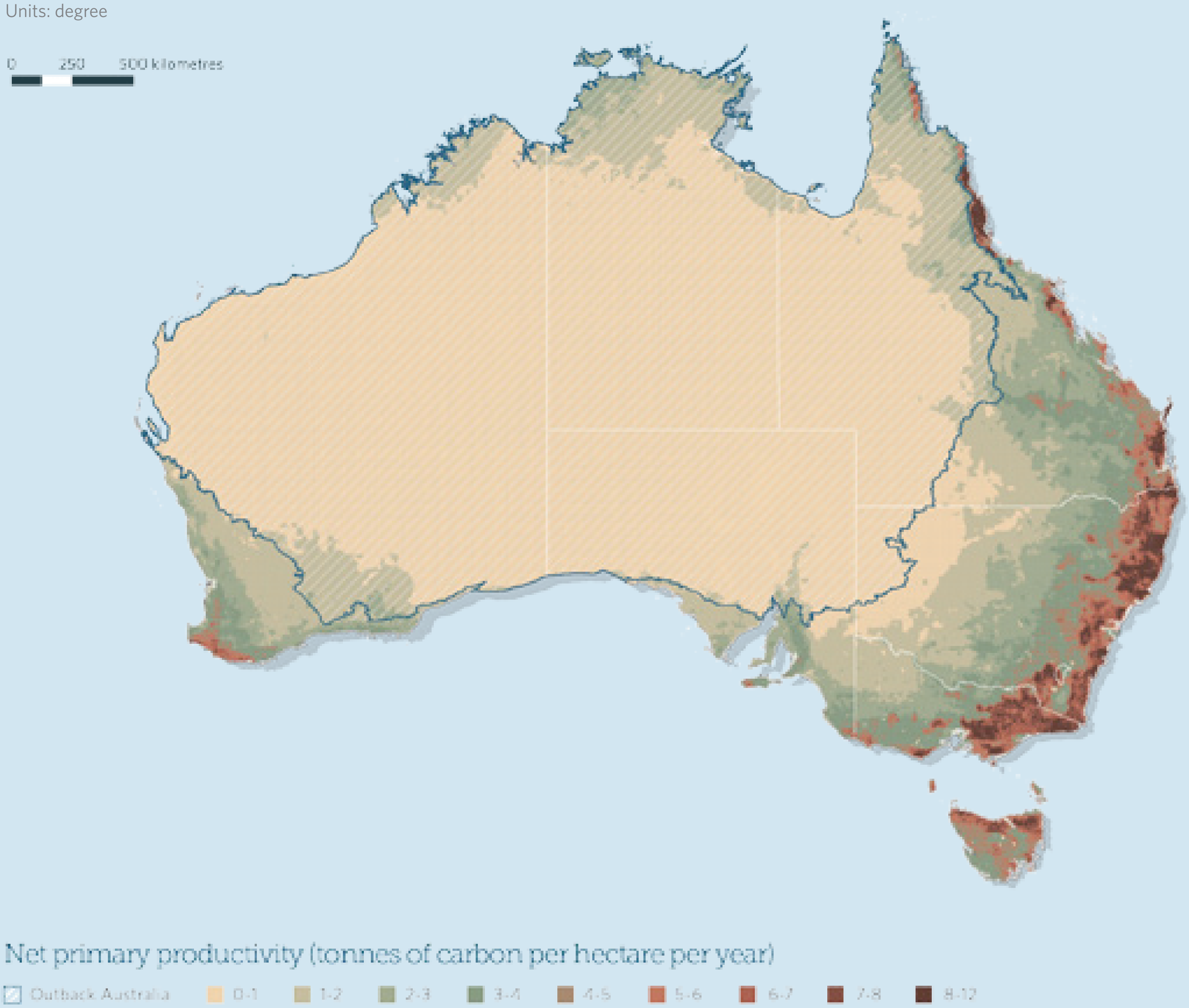
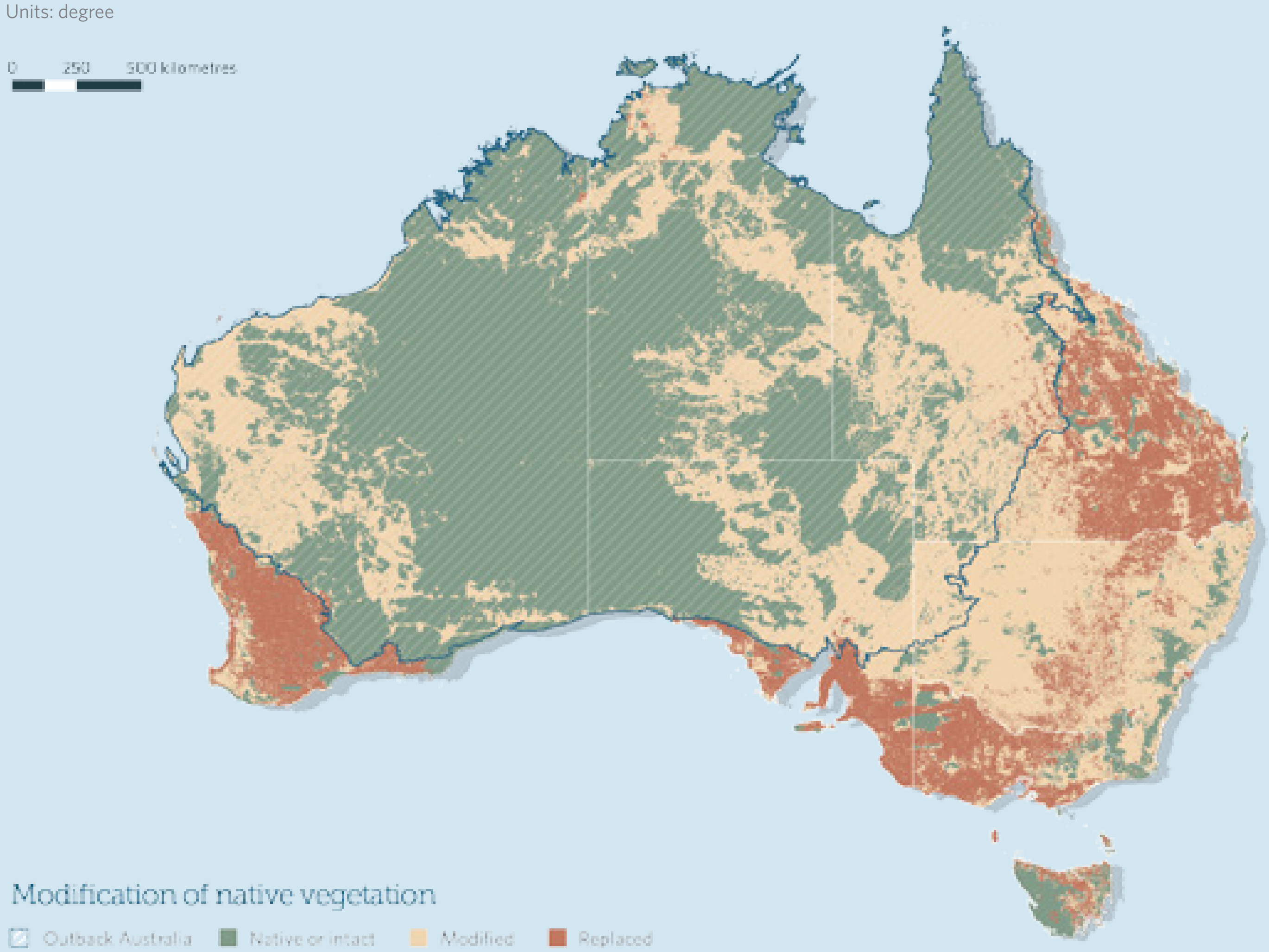


Figure design by The Pew Charitable Trusts

Figure 4

Extent of Vegetation Transformation Across Australia

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: degree



Note: 'Native or intact' or 'residual' indicate that the vegetation structure and composition have high integrity; 'modified' indicates that vegetation communities are still dominated by native species, but the composition and structure are altered (e.g. by pastoralism); 'replaced' indicates that much of the vegetation is replaced by non-native species.

Source: Thackway and Lesslie (2005, 2006, 2008)

Figure design by The Pew Charitable Trusts

The annual Birdsville Races, held in Outback Queensland each September, attract huge crowds from across Australia. Birdsville is located on the edge of the Simpson Desert in far south-west Queensland. Its racecourse is on a natural clay pan and is known to be one of the best dirt tracks in the country.

Pastoral leases for cattle, sheep and goats cover around 40% of the Outback. This cattle muster is on the Peninsula Development Road, near Meluna, Cape York Peninsula, Queensland.

The Australian Outback is not an administrative or political entity. As defined here, it comprises all of the Northern Territory, most of Western Australia, South Australia and Queensland, and far north-western New South Wales (Table 1). This jurisdictional segmentation has long made it difficult to develop coherent planning and policy across the Outback and much of its governance base lies remote from the Outback itself, in the capital cities of Brisbane, Sydney, Adelaide, Perth and Canberra. In many cases, the Outback components of these states are treated largely as neglected backyards.

2.2. The Outback character

Society and life in the Outback are distinctive. The colours and smells and climate of Cape York Peninsula differ from those in the desert country west of Alice Springs or the temperate woodlands near Kalgoorlie. But for people living on these lands, the lifestyles and challenges are similar and markedly different to those of Australians resident in urban areas, or even those in the largely transformed agricultural lands lying between the cities and the Outback.

Across thousands of kilometres, people and communities in the Outback must deal with social concerns about remote schooling for their children; intermittent, expensive and unreliable supplies; and limited transport, health and other services. Pastoralists in the Gulf Country, rangers on private conservation lands in the Kimberley, Aboriginal people managing their clan estates in the western deserts, and council workers in towns of remote South Australia all need to deal with drought, fire and invasive species over big landscapes, with small budgets and just a few workers. These concerns may seem remote and unfamiliar to those in the distant centres of political power. Across all Outback regions, there are similarities in the solutions to these challenges and efficiencies in working collaboratively over very large areas to develop and implement such solutions (see Insight 2).

A defining and pervasive feature of the Outback is its deeply interwoven fabric of historical, environmental, social and economic threads. This is more than a simple coincidence of factors: for the Outback, the interconnectedness and interdependence of diverse factors are far deeper than the fact that they happen to be in the same geographic region (Robin *et al*. 2010).

Table 1

Outback Areas, in Relation to Australia as a Whole

Jurisdiction	Total area (km^2)	Area (km^2) in Outback (% of total area)	% of total Outback
Western Australia	2,527,013	2,271,739 (89.9)	40.3
Northern Territory	1,347,792	1,347,792 (100)	23.9
Queensland	1,729,742	1,118,066 (64.6)	19.8
South Australia	984,322	825,115 (83.8)	14.6
New South Wales	801,217	72,033 (9.0)	1.3
Victoria	227,444	0	0
Tasmania	68,401	0	0
Australian Capital Territory	2,358	0	0
External Territories	995	0	0
Total	7,689,283	5,634,744 (73.3)	100

Figure design by The Pew Charitable Trusts

Insight 2

Why consider a coherent perception of the Outback?

Remote Australia is diverse – geographically, biologically and culturally. However, this can obscure the great similarities across the Outback in the threats its regions face, the fundamentals of the communities present, the opportunities on offer and the policies needed. These differ markedly not only from urban areas, but also from more closely settled agricultural regions towards the coast. Although the detail may show some variation among Outback regions, the big landscapes of remote Australia have a consistent range of threats, opportunities and solutions.

> The Outback represents a remarkable opportunity to foster truly sustainable development, which combines safeguarding nature, sustaining flourishing cultures and securing social and economic advancement.

In addition to the similarities in approach needed throughout the remote lands, there are synergies of resources, knowledge and motivation that can be attained by a national focus that crosses state boundaries. As a coherent entity, the Outback resonates more strongly at national and international levels than does a region-by-region or project-by-project focus. Concentrating on the future of the Outback as a whole also helps integrate consideration of ecology, culture and economy. The Outback represents a remarkable opportunity to foster truly sustainable development, which combines safeguarding nature, sustaining flourishing cultures and securing social and economic advancement. Without strategic consideration and commitment, Australians risk irreparably losing much of what is special about our Outback heritage.

The Outback is different. Commonalities across regions distinguish it from the rest of Australia:

- ecology is different in the Outback – it is shaped by more infertile soils and greater climate variability than in the rest of Australia;
- land management issues are more similar across the Outback than they are between Outback and adjacent areas – as an example, the control of camels or the management of fire needs to be managed across vast tracts of sparsely inhabited country and multiple tenures; and
- social circumstances in the Outback are also different – Aboriginal Australians own much of the land but suffer chronic impoverishment, population is sparse and economic choices are limited.

An Outback focus has cultural and political resonance:

- because the Australian population is so weighted towards the coast, Outback residents will achieve greater influence as an entity than they will region by region;
- the Outback as a whole is likely to have a stronger connection with most Australians, and indeed most people elsewhere in the world, than its less well known individual parts; and
- because of its cultural significance, conserving the Outback is a more powerful idea than saving particular places.

An Outback focus promotes synergies:

- sharing ideas, resources and information generates synergistic benefits, particularly important because of the sparseness of population and resources in particular regions; and
- there is greater potential for integrating ecological, social and economic goals.

Another feature of the Outback is its perverse, contested, ill-defined and shifting meaning and significance in the national context:

'[It has] long been part of the romantic ethos and psyche of ordinary Australians. However, the qualities that led it to these values are now being replaced by less well defined attributes. … No longer is the European conquest of a harsh environment to feed a starving world seen as romantic or sublime' (Fitzhardinge 2012).

'Many Australians view remote Australia in terms of extremes: variously as a last frontier, a vast unsettled and isolated terrain, a place of Aboriginal crisis, or the 'heart' of the nation (often including a romanticised notion of the 'rugged outback' life). It is also seen as an economic wasteland, a place of market failure and extreme poverty (even a 'failed state'), somewhere to drive when you retire, or more recently a quarry for the mining boom driving the nation's economic performance. To some it is a legitimate part of the Australian narrative only because of the heritage status of the pastoral industry and the major resource development projects scattered throughout it.

It is worth noting here the fundamental discord between these opinions and the thinking of many Aboriginal Australians, who see remote Australia as Country, a place that nourishes and provides meaning and identity: their spiritual and physical home. One set of views is centred on a desire to dominate and tame the space, while the other lives in and adapts within it. This discord is part of the complex contest that needs to be addressed and resolved' (Walker *et al.* 2012).'

> One set of views is centred on a desire to dominate and tame the space, while the other lives in and adapts within it.

Time is different in the Outback. This is one of the most ancient landscapes on earth. Its environments have been crafted through millions of years of isolation. Much of the spiritual potency of Indigenous culture resonates because of its recognition and connection to this deep time and timelessness – of the power in the landscape enduring since the remote beginnings. Across much of its extent, ecology operates mostly on scales of decades, centuries and millennia: occasional years of good rainfall waken the land from a long dormancy, episodic floodwaters bring life to the dry lands, reshape the landscape and regenerate or revitalise many plant and animal species that have eked out a meagre existence over many years. This slow but deep rhythm is unfamiliar to most Australians and conventional attempts to use and manage this land in an annual, political or other regular cycle are ill-matched to this beat.

And place is different in the Outback. The horizon is distant, one's position in the landscape is smaller, the sense of space is tangible and the night sky seems closer. It is a vast land. But it is also profoundly interconnected. In Indigenous culture, songlines and dreaming tracks criss-cross the landscape (Bradley and Yanyuwa Families 2010), paintings depict the complex pattern of links between places and their meanings, and stories thread individual sites to a broader landscape narrative. Likewise, a thin mesh of modern transport routes now connects remote population centres and these modern arteries themselves have taken on a fabled resonance: the Ghan, Gunbarrel Highway, Indian Pacific Railway, Stuart Highway, Birdsville Track, Canning Stock Route and Gibb River Road have become part of the lure and feel of the Outback.

Intricate connectivity, even across vast distances, is also part of the fabric of the Outback's natural environments. Populations of many of the Outback's animal species ebb and flow across the landscape, at local, regional and continental scales, with such movements mostly driven by the area's capricious climatic variation. The scale, periodicity, regularity and triggers of dispersal vary widely among Outback species – they move, and must move, as in a maze of songlines across this land. Our concept of the land and our ability to manage it, must work at such scales by recognising and reinforcing such connections. We must see the patterns in time and space.

Of course, water is the most profound of the interconnected features of the Australian Outback: rain falling in north-western Queensland may lead months later to the filling of Lake Eyre thousands of kilometres distant. And beneath much of the Outback, artesian basins and other subterranean water supplies provide unseen connections across vast areas. In this dry landscape such flows are vital and the health and condition of one place may be inextricably dependent on how well we manage another place hundreds of kilometres away. Connectivity over vast distances is a fundamental but frail trait of Outback life and the maintenance of this connectivity is critical for its future.

While there are many consistent features across the Outback, its landscape is also diverse and can be segmented in many ways – by climatic zones, catchments, bioregions, ecoregions and state and territory boundaries. Some of this variation is described in regional portraits over the following pages (see Spotlight 1, Figure 5).

Red dunes are a defining feature of the Outback. This dune, known as 'Big Red,' is the highest of the 1,100 dunes in the Simpson Desert, south-west Queensland.

Spotlight 1 **Outback regions**

The Outback is a jigsaw with many parts, but there is a set of major environmentally coherent units that collectively make up most of the Outback's extent. In this section, we briefly describe some of the distinctive features of those main units.

Seven deserts

The Outback is an extremely varied place and hard to typify, but its vast deserts may be the centrepiece. These occur discontinuously across the arid areas of central Australia, extending to the coast in an arid fringe between the Pilbara and Kimberley in north-western Australia. Collectively, they cover about 20% of the Australian mainland. Their boundaries are generally indistinct, but there are seven main deserts – the Great Sandy (about 270,000 km^2), Little Sandy (about 110,000 km^2), Gibson (about 160,000 km^2), Tanami (about 180,000 km^2), Great Victoria (about 350,000 km^2), Simpson (about 180,000 km^2) and Sturt Stony Desert – Strzelecki desert system (about 110,000 km^2) – loosely within two main groupings (the Western and Central desert systems). The characteristic Outback desert landscapes comprise a series of parallel red sandy dunes alternating with interdune flats (swales). However, the dune systems are weakly defined or non-existent in some Outback deserts and some (most notably Sturt's Stony Desert) have a surface layer of small stones (gibber) rather than deep sands.

Vegetation patterns vary among desert environments. Most are well vegetated with extensive hummock grasslands dominated by spinifex *Triodia* species, *Acacia* and other diverse shrublands, and mallee and other woodlands, but some are largely unvegetated. In many deserts, there may be marked differences in environments between dune crests and adjacent swales. Good rainfall events may markedly transform the appearance of Outback deserts, bringing pulses of plant growth, flowering and seeding, and the emergence of many ephemeral plant species and dormant animal species. In some Outback deserts, there may be mass breeding of waterfowl in usually dry lakes and depressions.

The deserts are rich in life, with many species intricately adapted to desert living, and many endemic species. Highly specialised desert animals, indeed some of Australia's most strange and fascinating species, include the Thorny Devil and the two species of marsupial moles, the Kakarratul and Itjaritjari. The deserts support a diverse reptile fauna, with many species occurring at site level and much variation in species composition between different desert regions.

Most Australian deserts are not barren expanses of sand or rock. The Outback supports a wide diversity of native plants, including specialised dry country species, such as this Sturt's Desert Pea.

Australian deserts are home to an exceptional variety of reptiles including the unusual Thorny Devil, an ecological specialist, feeding almost solely on ants.

Given the sparseness of permanent water sources, there are no major towns in the desert systems, but there are many small Aboriginal communities and several impermanent mining communities. Pastoralism has a fragile foothold in some deserts, mostly at the fringes. Most of Australia's largest conservation reserves occur entirely or largely in the Outback deserts: these include the Southern Tanami Indigenous Protected Area (IPA) (10.2 million hectares), Ngaanyatjarra IPA (10 million ha), Northern Tanami IPA (4.1 million ha), Simpson Desert Regional Reserve (2.9 million ha) and the Great Victoria Desert Nature Reserve (2.5 million ha).

Notwithstanding the lack of intensive modification, there has been substantial biodiversity loss in all Outback deserts. The decline of wildlife and the degradation of environments have mostly been due to the spread of introduced herbivores (particularly rabbits and camels) and carnivores (cats and foxes), and changes in fire regime since European settlement. Degradation has been particularly pronounced at and around water sources, pivotal to much desert ecology. Many desert mammals have become extinct over the course of the past century and many desert species are now threatened with extinction: notable examples include the Bilby, Night Parrot, Mala, Sandhill Dunnart and Tjakura (Great Desert Skink).

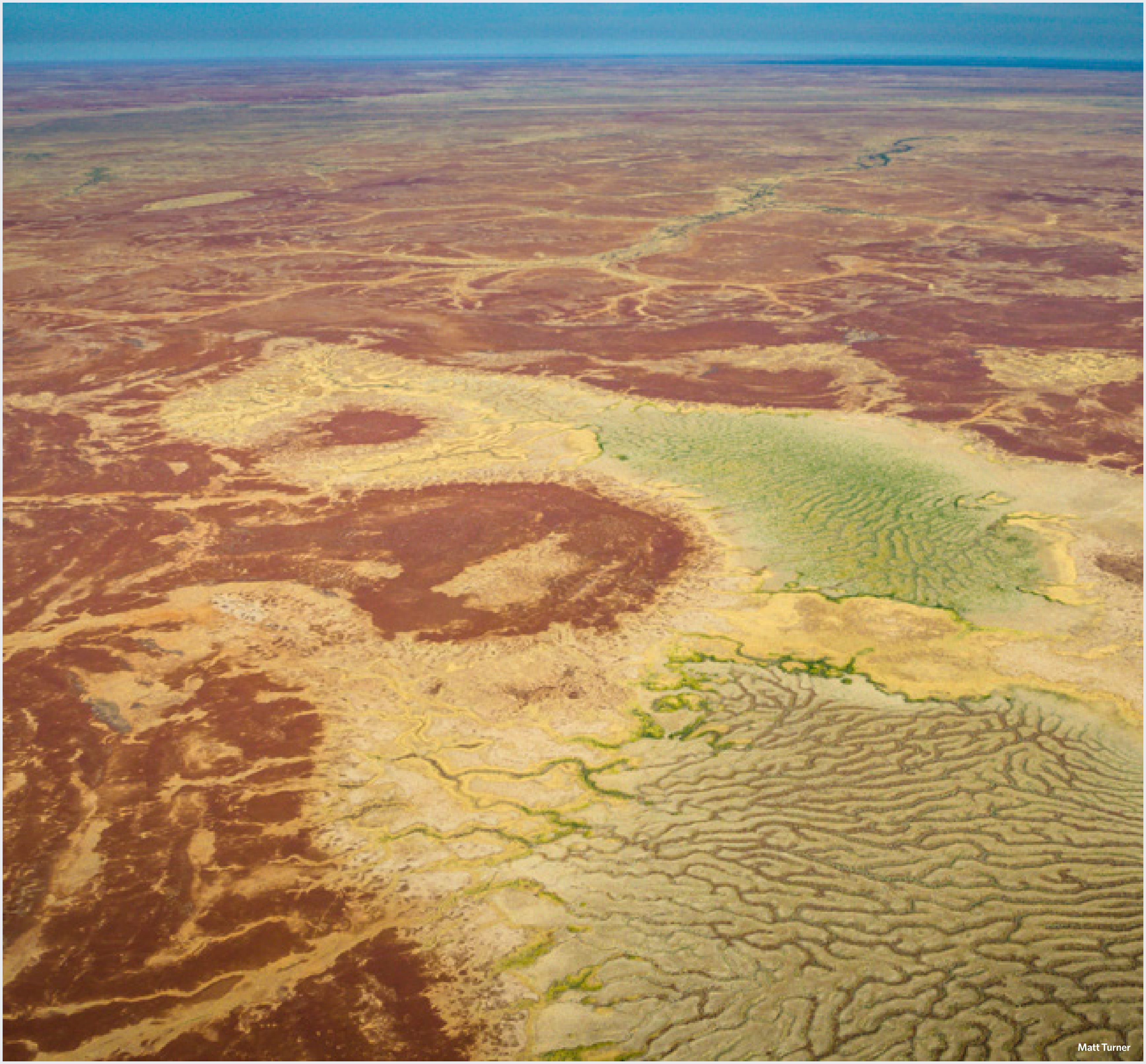
Inland ranges

Much of inland Australia is a subdued and subtle landscape, flat and superficially featureless. But there are notable exceptions: a patchy series of low but rugged mountains, including the Flinders, Gammon, Gawler, Musgrave, MacDonnell, and Petermann ranges. These frame and provide a dramatic contrast to the extensive lowlands. They are remarkably old features, long forming the backbone of the Outback landscape. Their grandeur, antiquity and utility (particularly for provision of hidden waters in a dry land) have made them a potent bedrock of Indigenous belief. They are also stunningly beautiful and evoke a sense of awe and wonder to the Outback. They are pivotal to much Outback ecology, providing some refuge to plants and animals from periods of inhospitable climates, and from some other threats, over long and short time scales; providing a palette of microclimates and substrates that is unusually varied in an Outback context; serving as centres of endemism and speciation (particularly for species with limited dispersal ability, such as land snails); providing the headwaters for many Outback watercourses and harbouring critical water sources within gorges and springs; and offering a more complex fire mosaic than typical of the relatively featureless surrounds. Examples of significant biodiversity in the Inland Ranges include the Warru (Black-footed Rock-wallaby) across many of the Inland Ranges and Yellow-footed Rock-wallaby in the Flinders Ranges, the critically endangered Central Rock-rat, dozens of narrowly endemic land snail species and fire-sensitive plants.

Large sections of the inland ranges are now included in some of the Outback's premier national parks and Indigenous Protected Areas, with the largest being the West MacDonnell National Park (2.6 million ha). These offer some significant protection against environmental threats, but many threats occur across all land tenures. The major factors detrimentally affecting biodiversity in the inland ranges include extensive fire; invasive grass species (particularly Buffel Grass), which have direct impact on plant and animal species and also exacerbate the impact of fire; and feral animals – notably including red fox, feral cats and, in many areas, goats, donkeys and horses. The rugged nature of much of this environment makes control of these factors difficult and expensive. There are few towns in the inland ranges, but the important regional centre of Alice Springs straddles the MacDonnell Ranges.

Channel Country

Spanning much of the latitudinal breadth of the continent and encompassing an area of 1,140,000 km^2, the Lake Eyre Basin is one of the world's largest internally draining wetland systems. All Outback regions show substantial variation in character within or between years, but this variation is most extreme in the Channel Country within the Lake Eyre Basin, with little surface water in most years, but in years of good rainfall flooding episodes lead to long continuous and highly productive river systems and vast lakes teeming with life.



Aerial view of the Listore Creek wetlands in Queensland's Channel Country. This area has a dramatic boom–bust cycle, with long dry periods broken by intermittent floods that bring water from the monsoonal north into the arid heart of the country. The productive floodplains come to life, and waterbirds and other wildlife breed prolifically.

A bird's-eye view of the intricate network of waterways that makes up Eyre Creek in the heart of Outback Queensland's Channel Country.

Chenopod shrublands are the main vegetation type in the largely treeless Nullarbor Plain, which stretches across the length of the Great Australian Bight. The Nullarbor is the world's largest single exposure of limestone bedrock, covering an area of about 200,000 km^2.

Much of the Channel Country is used for pastoralism, with less than 10% of the area reserved. There are no large towns in the region.

Mound springs are a distinctive conservation feature mostly associated with this region. These support many narrowly endemic species and have been particularly susceptible to degradation by livestock and feral herbivores, weeds and water extraction.

Nullarbor Plain

Named for what it lacks on its surface – trees – the vast, flat Nullarbor Plain has instead a dramatic underground topography with cave systems that harbour many unique animals. The 200,000 km^2 plain has the largest contiguous karst system in the world (Miller *et al*. 2012) – an immense limestone block (made from skeletons of marine animals) riddled with sinkholes, caves and subterranean rivers and lakes. It was lifted from the ocean 14 million years ago as the Australian continental plate slid beneath Indonesia. The Nullarbor meets the Southern Ocean with formidable cliffs and sandy beaches and melds into desert in the north. It functions as a barrier between eastern and western Australia – many western species are at their eastern limit there and vice versa for eastern species.

Most of the plain is undulating with low rocky ridges separated by shallow clay depressions (known as dongas). Its characteristic vegetation, covering about 85% of the area, is saltbush – small, drought-resistant, salt-tolerant shrubs. Trees are scarce because of the chalky (calcareous) soils and aridity but there are woodlands of mallee, other eucalypts, she-oaks and wattles in peripheral areas. Rainfall averages 150 to 250 mm per year, but it is highly erratic and most years receive much less than the average. Potential evaporation exceeds 2000 to 3000 mm per year (Australian Water Resources Council 1976).

The major land uses include sheep grazing, traditional Aboriginal uses and conservation. About one-third of the area is pastoral leases (mostly in Western Australia on the coastal edge) and there are also large areas of unallocated Crown land. Pastoralism was first established in 1858, but many enterprises have been developed only recently, in the 1960s. Although there has been almost no clearing, there have been significant losses of biodiversity values with extinction of about half the mammal fauna and degradation of vegetation. The major threats are feral animals (foxes, cats, camels and rabbits), stock (sheep), weeds and altered fire regimes (infrequent, extensive wildfires).

The Nullarbor Plain is considered to be relatively species poor but knowledge is incomplete, particularly of subterranean life (McKenzie and Robinson 1987; May and McKenzie 2003). Many caves host invertebrates,

For many Australians, part of the 'Outback experience' is crossing the Nullarbor Plan, which traverses the southern border region between South Australia and Western Australia. Independent travelling through the Outback is increasingly popular and serves as a significant rite of passage, particularly in retirement.

such as spiders, crustaceans, centipedes, cockroaches and carabid beetles (troglobites and troglophiles) (Morton *et al*. 1995a). Many of these species are poor dispersers, so are endemic to individual systems. Some deeper caves support the particularly unusual Nullarbor cave slimes – mantles or curtains of microbial biofilm hanging from cave surfaces. Isolated from any organic derived from photosynthesis, they oxidise ammonia to make their living (Tetu *et al*. 2013).

Great Western Woodlands

The Great Western Woodlands are indeed great – the largest remaining wild Mediterranean-type ecosystem in the world (CIESIN and WCS 2003; Watson *et al*. in press) and with outstanding plant diversity. Much of this area sits on an ancient piece of the earth's surface – the 2.4 to 3.7-billion-year-old Yilgarn Craton. Extreme geological stability and lack of glaciation have allowed uninterrupted opportunities for evolution over about 250 million years.

Spanning two climatic zones, it is a biologically rich interzone area that overlaps with the iconic global biodiversity hot spot of the southwest (Myers *et al*. 2000) and in the north and east with the Great Victoria Desert and the Nullarbor Plain.

The region is mostly flat or undulating and highly eroded. Large sand plains are relieved by laterite breakaways and salt lakebeds. The old infertile soils occur in a complex mosaic of different types that contributes to plant diversity. There is almost no permanent water. The climate is arid to semi-arid, with warm, dry summers and cool, wet winters. Rainfall is variable and unpredictable.

There are more than 3300 species of flowering plants, including about 30% of Australia's eucalypts (Watson *et al*. 2008). Reptile richness is also outstanding, with 138 known species.


Barbara Madden

The Great Western Woodlands, near Kalgoorlie in Western Australia, overlap with an identified global hot spot for plant diversity. The woodlands contain 20% of Australia's plant species – including 30% of eucalypt species – and provide essential habitat for many rare and threatened animals, such as the Chuditch and Malleefowl.

The Great Western Woodlands have been saved from the fate of other southern woodlands in Australia – 85% cleared for agriculture – by a lack of water, low fertility and chance (a crash in wheat prices and drought stopped proposed development in 1969). But, as is the case elsewhere, much of the original mammal fauna is gone. More than 40 regional ecosystems are threatened (National Land & Water Resources Audit 2002 database). Major threats are feral animals (foxes, cats, donkeys, rabbits, goats), altered fire regimes (with extensive wildfires now apparently more common than previously), stock grazing and weeds.

The Great Western Woodlands region extends over an area of about 16 million hectares. Unallocated crown land comprises about 60% of this area, with 18% devoted to pastoral leaseholds. Some smaller areas have been cleared for dryland cropping and introduced pastures. There are 46 conservation reserves, some large, with a total area of about 13% of the region.

The most economically significant land use is mining, mostly for gold and nickel. The gold triggered a rush in the late 1880s, which brought 50,000 people, infrastructure and large-scale logging. The area is sparsely populated, with most of the 30,000 or so people living in towns. There are large areas with very few or no residents. Mining and mining exploration now spans 63% of the Great Western Woodlands area.

An ambitious collaborative community conservation project, Gondwana Link, is underway to connect the Great Western Woodlands to the wet forests of the southwest, a distance of over 1000 kilometres.

Lake Johnson and adjacent Salmon Gum woodlands in the Great Western Woodlands in south-west Western Australia. These woodlands are the largest and most intact Mediterranean-type temperate woodland ecosystem on Earth.

Pilbara

Lizards, stygofauna and miners are particularly evident in the Pilbara – each with global significance – and, not coincidentally, the Pilbara also has some of the oldest rocks in the world. The region is geologically defined by the Pilbara Craton, a great block of hard rock laid down 2.5 billion to 3.5 billion years ago, which is exposed in the north as undulating hills and plains of granite and greenstone, and overlaid by rugged ranges in the south (Myers 1993). The Pilbara is rich in iron, which precipitated from acid seas due to oxygen-generating photosynthetic cyanobacteria, whose 3.4 billion-year-old fossilised remains (stromatolites) in the Pilbara are some of the oldest evidence of life on Earth (Allwood *et al*. 2007). The endurance of this landscape has created stable groundwater refuges for crustaceans that originated in Pangean and Gondwanan times.

The Pilbara's average annual rainfall is 290 mm and its soils are mostly skeletal, shallow and stony. But its topography is complex and so is its vegetation (with more than 2000 taxa), which is strongly influenced by geology and fire history (Maslin and van Leeuwen 2008). The Pilbara is rich in wattles and has extensive shrublands and woodlands dominated by wattles and spinifex, as well as eucalypt woodlands, grasslands and saltmarshes (George *et al*. 2011). It also has an abundance of springs and river pools with lush riparian vegetation.

Too-frequent wildfires and over-grazing (mainly by sheep, whose numbers peaked at 1.3 million in the 1930s) have changed the vegetation in many places and stripped the organic surface soils (George *et al*. 2011). Riparian areas have been extensively degraded. In many places, native grasses have been replaced by invasive Buffel Grass. Land uses are mainly grazing – about 60% is under pastoral lease (mainly cattle) – and mining. About 10% is in conservation reserves (George *et al*. 2011).

In a continent with extremely rich lizard fauna, the Pilbara stands out for lizard diversity – with the most gecko species and also high numbers of dragons and skinks. Many are unique to the region, including about a quarter of its skinks and geckos (Doughty *et al*. 2011).

About 350 species of stygofauna (underwater invertebrates and fish), nearly all endemic, have been found in Pilbara aquifers and there are likely to some hundreds more (Halse *et al*. 2014). More than 50 species have been found in a single bore. These are among the richest stygofauna communities in the world. Groundwater drawdown, due to mining is a threat to stygofaunal communities.

For an arid region, the Pilbara is also rich in surface aquatic invertebrates – about 1200 species have been found, with some 20% endemic to the region. Many species in the Pilbara are yet to be described – including from recent surveys: 68% of more than 400 beetles and all but one of 22 scorpion species (Guthrie *et al*. 2011; Volschenk *et al.* 2011).

The Pilbara is also culturally rich, with the greatest concentration of Indigenous rock art in the world on the Burrup Peninsula (Environmental Protection Agency 1995).

Kimberley

The Kimberley is a distinctive and important landscape. Like the Top End (the northern half of the Northern Territory) and Cape York Peninsula, it is strongly monsoonal, with moderately high (to 1400 mm) rainfall occurring in a relatively brief wet season and a strong rainfall gradient diminishing inland. The Kimberley is notably rugged, with a deeply dissected and complex landscape dominated by sandstone, volcanic and laterite ranges and plateaux, and a wide array of tall eucalypt forests and woodlands, some with a distinctive tall palm understorey. The coastline is spectacular, with ranges steeply abutting the sea in many areas and a large series of offshore continental islands. The south-east and south-west Kimberley also include some areas of highly productive blacksoil plains in lowland flats around major rivers and isolated rugged ranges (including the World Heritage Purnululu National Park). The Dampier Peninsula is an unusual feature with deep red sands supporting a distinctive *Acacia*-dominated ('pindan') low woodland. Small patches of monsoon rainforests occur in fire-protected and unusually wet sites, particularly in the higher rainfall and more rugged areas.

The Kimberley biota shares many biodiversity elements with the other main high rainfall regions of the Outback – the Top End and, less so, Cape York Peninsula – but also supports a large number of narrowly endemic species, with the known number of these increasing rapidly with ongoing surveys. This has been best documented for land snails, for which initial inventories in the 1980s reported about 180 Kimberley endemic species from a sample of rainforest patches (Solem 1991), with subsequent surveys adding substantially more. But endemism is also a feature of many plant, reptile, mammal and frog species, among others. Some notable Kimberley endemics include the Black Grass-wren, Kimberley Rock-rat, Monjon (a very small rock-wallaby), Scaly-tailed Possum and Rough-scaled Python. Kimberley islands, and a small and diminishing part of the rugged and high rainfall Kimberley mainland, are also notable in maintaining a high diversity and abundance of many mammal species that have disappeared over the last century or so from almost all of their formerly extensive ranges. Coastal waters of the Kimberley are also notable in supporting rich and distinctive marine communities, and function as important breeding grounds for Humpback Whales (Department of Sustainability Environment Water Population and Communities 2012).

Sandstone escarpments dominate the landscape of the Cockburn Range in the Kimberley region, far north-west Western Australia.

A typical Pilbara landscape of mesas, escarpments, rolling hills and spinifex grasslands at Mount Frederick, Western Australia.

Dugong Bay in Western Australia's north-eastern Buccaneer Archipelago. The Outback has international significance due to its largely unmodified natural condition. Because most rivers have little or no degradation, coastal environments are also in unusually good condition, and Dugong Bay is an excellent example.

These unusual rock formations are at the southern end of the Bungle Bungle Range in Purnululu National Park – a World Heritage site in the Kimberley region of north-western Australia.

Some of the Outback's most important conservation reserves occur in the Kimberley, including Prince Regent Nature Reserve in the Mitchell Plateau area, and Purnululu National Park; and large areas have recently been established as Indigenous Protected Areas. Much of the more rugged north Kimberley region is Indigenous-owned lands. A significant proportion of the region is managed as pastoral estate, although management of many properties is low intensity. In marked contrast, parts of the south-east Kimberley are some of the most transformed lands in the Outback, with a major irrigation program supporting considerable expansion in the area of intensive horticulture. There are also some current and many proposed major mining and gas ventures. The total population size is low, with the largest towns comprising Broome (13,000 people), Kununurra (6,000), Derby (3,000), Wyndham (700) and Fitzroy Crossing (1500). As with most other Outback regions, major threats to biodiversity operating extensively in the Kimberley include largely uncontrolled and inappropriate fire regimes, feral animals and intensive development and water use. The Kimberley islands are particularly notable conservation assets, as it is likely that at least some of these may long provide some refuge against many threats that affect mainland populations of some threatened plants and animals.

Top End

The northern half of the Northern Territory, colloquially known as the Top End, is strongly influenced by a monsoonal (wet-dry season) climate and its rainfall is among the highest in the Outback, exceeding 2000 mm per year in the coastal northern extremity of the Tiwi Islands. Forest and woodland structure is better developed in this region than in most Outback regions. There are extensive savanna woodlands dominated by Darwin Stringybark and Darwin Woollybutt, pockets of rainforest in localised wet areas or sites sheltered from fire, extensive lowland floodplain grasslands and seasonally inundated *Melaleuca* forests and woodlands, heathlands in rugged Stone Country, and unusually diverse mangals (mangrove forests) and saltmarshes along the coastline. Many of Australia's largest rivers flow through the Top End and there is a wide range of wetland systems.

This region is extremely important for biodiversity, with many endemic species occurring particularly in the sandstone plateau of western Arnhem Land, many islands with high conservation value, and high species richness in rivers, wetlands and coastal systems. Characteristic or significant species restricted to this region include the majestic Anbinik tree, that dominates rainforests of the Stone Country of western Arnhem Land; a suite of mammals including the Black Wallaroo, Kakadu Dunnart, Arnhem Rock-rat, Northern Hopping-mouse, Kakadu Pebble-mouse, Northern Brush-tailed Phascogale, Sandstone Antechinus, Fawn Antechinus, Arnhem

Tropical savannas such as this one in Kakadu National Park, in the Northern Territory, are the most extensive vegetation type across northern Australia. Here, there is an open understorey with *Livistona* palms.

Leaf-nosed Bat and Arnhem Sheath-tailed Bat; one of Australia's largest snakes, the Oenpelli Python; highly restricted bird species such as the White-throated Grass-wren; and at least 200 plant species. There is an extraordinary diversity of invertebrate groups, particularly so for ants. The region is also a stronghold for many threatened species, including Gouldian Finch, Partridge Pigeon and Brush-tailed Rabbit-rat, and the rivers and coastal waters support critical populations of coastal dolphins – including the Australian Snubfin Dolphin and Australian Humpback Dolphin – and threatened river sharks and sawfish.

Significant conservation areas include Kakadu, Nitmiluk, Litchfield and Garig Gunak Barlu national parks, and some of Australia's largest and most important Indigenous Protected Areas (including Dhimirru, Djelk, Warddeken, Marthakal and Anindilyakwa). However, environments on more fertile soils (of high pastoral productivity) are notably poorly represented in the conservation reserve system. The total human population is about 200,000, with major towns including Darwin, Katherine, Gove and Maningrida. Indigenous people comprise about 25% of this population, but this proportion is substantially higher away from the few main towns. Compared with other Outback regions, there has been intensive environmental modification in some areas, mostly for agriculture, mining, forestry and residential development, but the total proportion cleared is less than 10%. More pervasive threats to biodiversity include weeds – particularly invasive pasture grasses such as Gamba Grass – that significantly increase fire intensity and transform environments, pests – particularly cane toads, water buffalo, pigs, cats and tramp ants – and frequent fires.

Gulf country

Between Cape York Peninsula to the north-east, the Top End to the north-west, the Channel Country to the south and the Gulf of Carpentaria to the north lies a weakly differentiated Gulf hinterland region. Rainfall in the region is less than in the Top End and Cape York Peninsula, and decreases further from the coast to the Inland. In evolutionary context, this low-rainfall area has been a barrier to dispersal of plant and animal species between the Top End and Cape York Peninsula; and the relatively low rainfall of this region means that it largely lacks the tall eucalypt forests and rainforest patches that characterise those higher rainfall regions. Instead, vegetation in the Gulf hinterland mostly comprises open woodlands, hummock grasslands, tussock grasslands and impermanent wetlands, with the latter two types best developed in the extensive Mitchell Grass Downs at the arid fringe of the Gulf region.

Much of this region is relatively flat, but there are some rugged (but typically low altitude) sandstone and limestone ranges, notably around Mount Isa. Some large rivers drain northward into the Gulf (including the Flinders, Nicholson and Gregory rivers), and in places these support dense riparian vegetation. There are also internally draining wetland systems (notably on the Barkly Tablelands).

S Murphy/courtesy of Australian Wildlife Conservancy

The Gouldian Finch, shown here at the Australian Wildlife Conservancy's Mornington Wildlife Sanctuary in far north Western Australia, is one of the most stunningly coloured birds in the world. These finches are in a group of grass-seed-eating birds – pigeons, finches and parrots – that has declined in recent decades in the tropical savannas. The composition of grasses in the understorey has been altered by grazing and shifting fire patterns, changing the food availability for some birds.

Most of the Gulf region is used for pastoralism and many of the Outback's most valued and productive pastoral enterprises occur in the Mitchell Grass country. There are also large mining ventures, notably at and around Mount Isa.

Relatively few plant or animal species are restricted to the Gulf region, but some notable animal examples include the Julia Creek Dunnart, Collett's Snake and Gulf Snapping Turtle. The Mitchell Grass Downs is also the primary refugial area for the Flock Bronzewing Pigeon and Long-haired Rat, two species that irrupt across much of the continent following favourable rainfall.

Relatively little of this region is included in conservation reserves, but a notable example is Boodjamulla (Lawn Hill) National Park, adjacent to the World Heritage-listed Riversleigh fossil site.

Cape York Peninsula

For much of the past three million years Australia and New Guinea have been linked by land through Cape York Peninsula, the last link severed just 6000 to 8000 years ago. With only 100 kilometres separation from its northern neighbour (part of the same continental plate), the biodiversity of Cape York Peninsula continues to be enriched by this connection. Bordered in part by two World Heritage areas – the Great Barrier Reef and the Wet Tropics – Cape York Peninsula itself has outstanding and globally significant biodiversity and other values that qualify much of it for World Heritage listing (Mackey *et al.* 2001; Hitchcock *et al.* 2013).

Undulating plains slope gently east and west from a ridge of low mountains and hills running parallel to the east coast. This backbone of 1.5-billion-year-old rock extends to New Guinea, its northern peaks forming islands in the Torres Strait. The climate is monsoonal, with about 80% of rainfall falling from December to March. Summers are hot and humid and winters mild.

About two-thirds of the Peninsula is eucalypt woodlands. There are also extensive paperbark woodlands and swamps, grasslands, rainforest and heathland. About a fifth of Australia's rainforest area occurs there, a harbour for many endemic species. One of the world's most species-rich mangrove systems lines both coasts (Abrahams *et al.* 1995).

With more than 3500 plant species, of which at least 264 are endemic to the region (Abrahams *et al.* 1995), Cape York Peninsula is an Australian centre of plant diversity, endemism and evolution (Crisp *et al.* 2001; Hitchcock *et al.* 2013). Orchids are one of many species-rich plant groups, with 62 genera (Abrahams *et al.* 1995).

The more than 500 terrestrial vertebrates on the Peninsula include a quarter of Australia's frogs, a quarter of the reptiles, a third of mammals and half of its birds (CYRAG 1996). Wenlock River has the highest diversity of freshwater fish of all Australian rivers (Abrahams *et al.* 1995; Hitchcock *et al.* 2013). At least 40 vertebrate species are endemic to Cape York Peninsula, including more than 20% of its frogs, reptiles and non-flying mammals (Mackey *et al.* 2001). The Peninsula is a transit site for birds travelling to and from New Guinea, an overwintering habitat for species coming from the south, a breeding habitat for species coming from New Guinea and part of a network for seasonal movements of wetland birds.

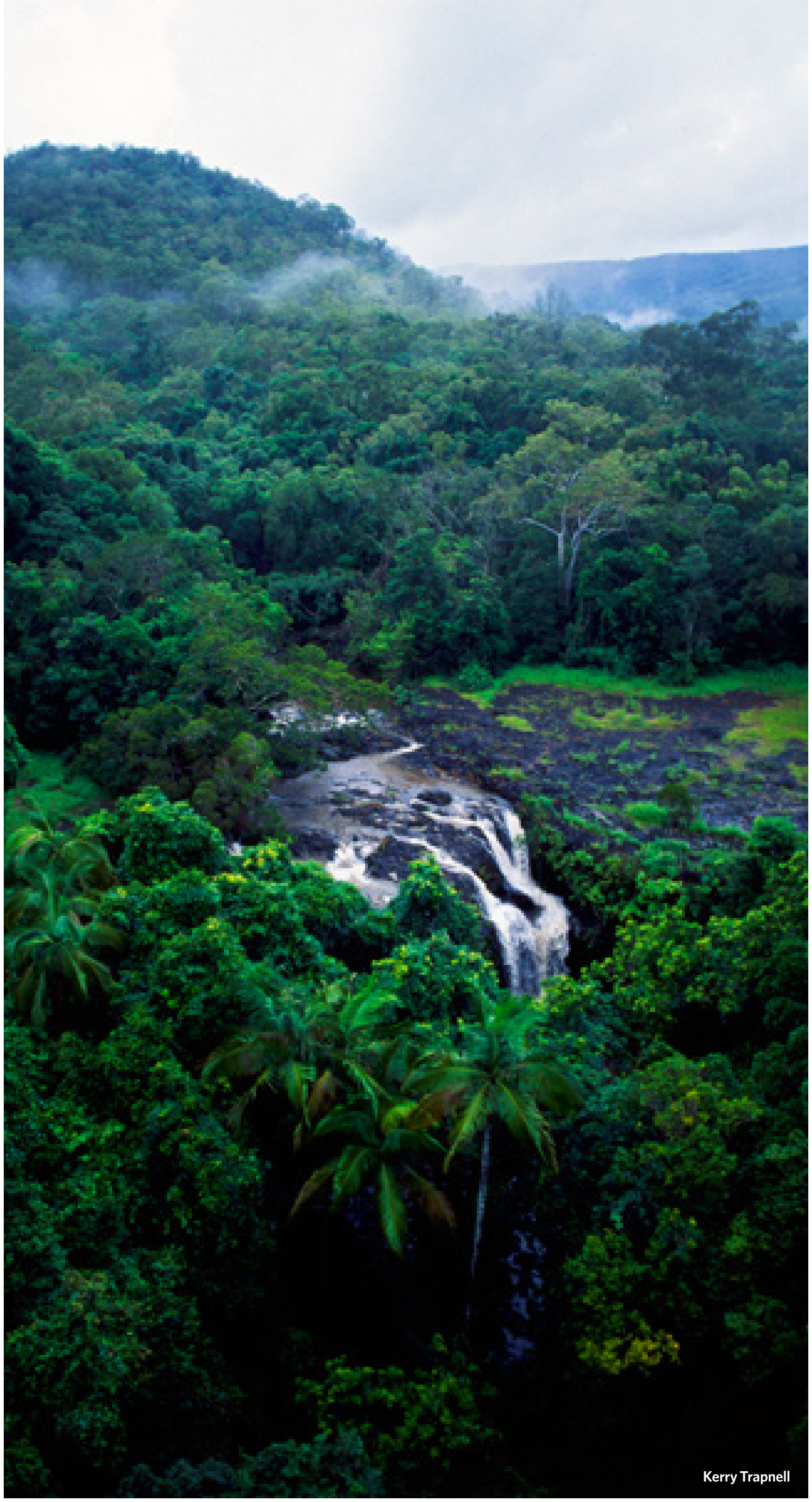
The few surveys show that the Peninsula is also rich in invertebrates. About 60% of all Australian butterfly species have been recorded there, a fifth of which are endemic (Abrahams *et al.* 1995). Two thousand species of moths and butterflies were collected on one seven-kilometre length of track in the McIlwraith Range.

Pastoralism is the most extensive land use on the Peninsula. Other commercial activities include mining, tourism and fishing. There are 12 small towns.

Although little gross disturbance has occurred, there has been gradual deterioration in conservation values, particularly due to the extensive impacts of stock grazing, inappropriate fire regimes and invasive species. More than a third of regional ecosystems are threatened (Sattler and Glanznig 2006).

Parts of the whole

All these regions are distinctive and have their own special values, but they also share core social, economic, and environmental traits and concerns. In all cases, broad-scale management is required to sustain and enrich existing values. This broad-scale approach is most appropriately and effectively considered and delivered coherently across all regions that make up the Outback.



Cape York Peninsula supports unusually varied environments. They range from almost unvegetated coastal sand dunes, such as the stark white silica dunes at remote Shelburne Bay (top right), to dense tropical rainforests like this example at Starke Falls (left), mangroves, and Melaleuca open forest, such as found at Strathmay (bottom right).

Figure 5

Locations of Some Broadly Defined Regions Within the Outback

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: degree

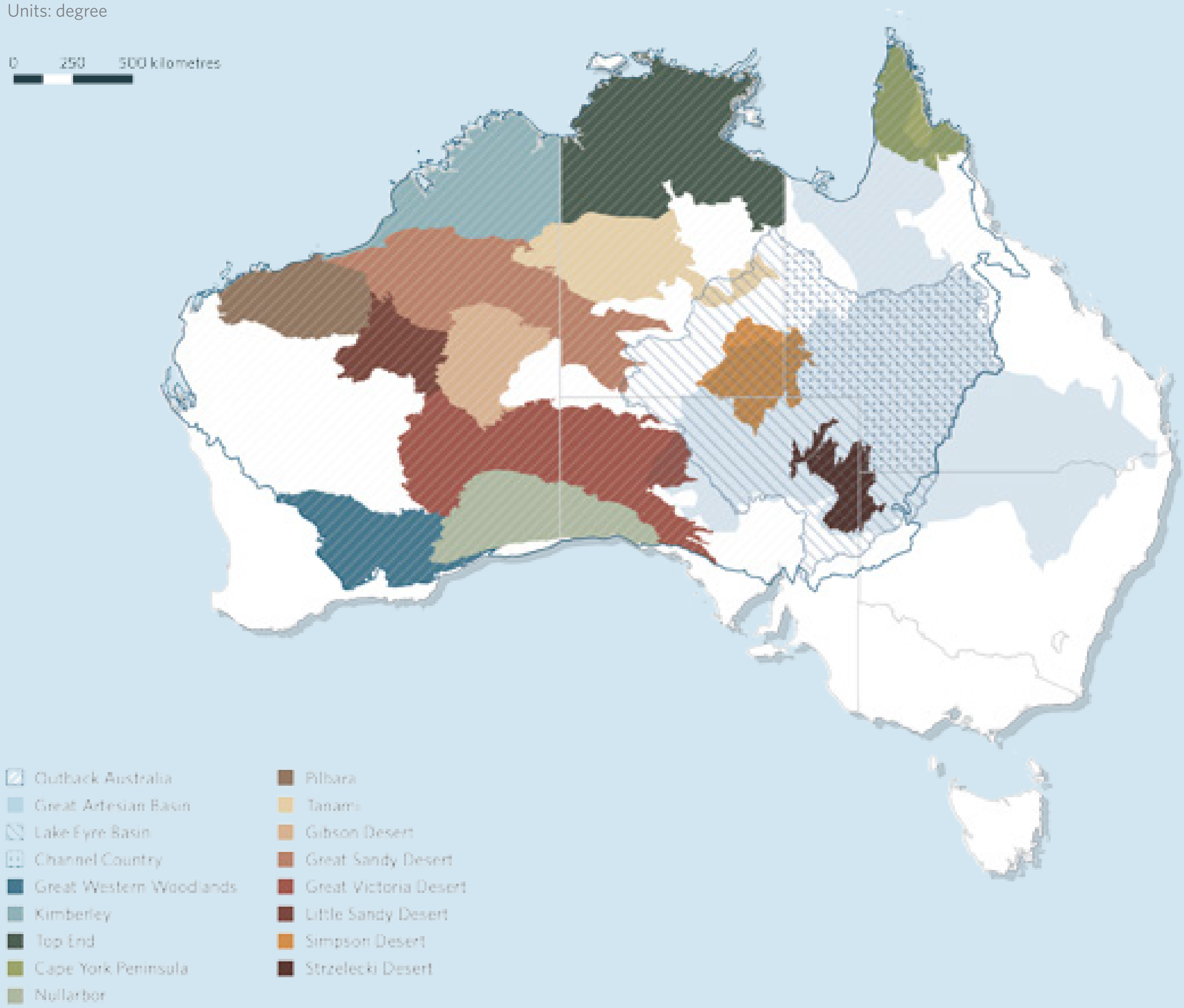


Figure design by The Pew Charitable Trusts

The main environmental distinction within the Outback is between the higher-rainfall (monsoon-driven) regions of northern Australia and the arid and semi-arid regions of central, and parts of southern and western, Australia. However, this variation is gradual rather than abrupt and there are many other more subtle environmental nuances across the Outback.

> The Outback constitutes about three-quarters of Australia's landmass, but is occupied by less than 5% of the population.

Many characteristics of the Outback are best defined by context and contradistinction with the features of the more settled and temperate Australia (Table 2). The Outback's climate, ecological basis and environmental intactness are notably different from Australia's more populated regions. Many natural, social and economic features of the Outback are interlinked: much is unpredictable and boom–bust; resources and communities are few and scattered. Indigenous people, lands, culture and socio-economic concerns are writ far larger in the Outback than in the national context.

The Outback constitutes about three-quarters of Australia's landmass, but is occupied by less than 5% of the population. And the circumstances and challenges of remote Australia are different from those that confront metropolitan or rural citizens. With such a small population base spread so widely, local and regional institutions are limited and often tenuous. Governance structures that work in metropolitan areas do not fit the Outback (Marsh 2012).

Table 2

Summary of Contrasts Between the Outback and the Rest of Australia

Feature	The Outback	Non-Outback
Area	5.6 million km^2 (73% of Australia's land area)	2.1 million km^2 (27% of landmass)
Geography	Continental core and remote coast	Mostly near-coastal periphery
Topography	Mostly flat, with isolated low weathered ranges	Includes the long spine of Australia's tallest mountains
Climate	High to extreme variability; long dry periods interspersed with shorter periods of high rainfall	Less variability and less extreme
Soils	Most highly infertile	More fertile
Natural productivity	Very low or highly seasonal in wet season, boom and bust cycles, annually or irregularly	More productive, rainfall and growth less seasonal
Cover of native vegetation	Mostly woodlands, hummock grasslands and shrublands; >95% intact	Originally mostly extensive areas of diverse forests, now >30% cleared
Rivers	Mostly free-flowing, <5% of water taken for exploitative use	Most rivers are dammed; typically >20% of water diverted for exploitative use
Population	800,000 (<5% of Australian population)	21.9 million (96% of total Australian population)
Population density	0.14 people per km^2	10.4 people per km^2
Indigenous population	25% of Outback population	<5% of total non-Outback population
Indigenous land tenure	>20% of land area owned by Indigenous people, with native title rights over extensive additional areas	<2% of land area owned by Indigenous people and limited additional areas for which native title rights apply
Economy	Relatively limited: intensive mineral production, extensive pastoralism, government services, tourism	More diverse: manufacturing, mining, horticulture, forestry, tourism, government services

Table design by The Pew Charitable Trusts

Picturesque Mitchell Falls is located on the remote Mitchell Plateau in the far north of Western Australia's Kimberley region. The plateau, part of Mitchell River National Park, is cut off from road access during the wet season. It is home to the endemic Darngarna palm, which can grow to 18 metres tall and live for up to 280 years.

3. The Outback environments are of global significance

More than seven billion people live on the Earth's 150 million km^2 land surface. Human influence has transformed the planet. Despite global commitments to maintain biodiversity, the world's natural environments and the biodiversity they harbour are diminishing rapidly (Secretariat to the Convention on Biological Diversity 2010; Zalasiewicz *et al.* 2011). The rate of environmental loss will continue to increase with further rapid growth in human populations and their resource demands and will be further exacerbated by climate change. Predictions of the Earth's future are stark: 'The resilience of many ecosystems is likely to be exceeded this century by an unprecedented combination of climate change, associated disturbances (e.g., flooding, drought, wildfire, insects, ocean acidification), and other global change drivers (e.g., land use change, pollution, overexploitation of resources)' (Parry *et al.* 2007). The Outback, as one of the largest wild and lightly populated areas on Earth, is one of the few places where conscious planning based on existing strengths could have a high likelihood of averting such a dire outcome.

> There are few remaining large and largely natural areas left on Earth: the boreal forests and tundra of far North America, Siberia and Greenland; the Sahara; the rapidly diminishing wildlands of the Amazon basin; the Himalayas and Tibetan plateau; and Outback Australia.

In the future, most of nature will occur in fragments or in a transformed state and the vestiges will be inadequate to protect most species. Increasingly, the best outlook for retaining biodiversity will be in large areas in which ecological processes have been maintained, and which are large enough to offer some resilience to new threats. Such large natural areas will also become increasingly valuable to humans for environmental services (such as the provision of oxygen and water) and to give future generations a sense of, and access to, a natural world. Where are such places?

3.1. Condition, extent and naturalness

Imagery taken from space reveals the earth to be beautiful, an object of awe and wonder. However, that imagery also shows an inexorable transformation, as the world's environments become more modified and nature retreats. The imagery can now be used to define and track the world's last remaining large areas of predominantly natural environments.

This is the context and perspective taken in the 'Last of the Wild' study, an analysis undertaken by the Wildlife Conservation Society and the Center for International Earth Science Information Network (http://sedac.ciesin.columbia.edu/data/collection/wildareas-v2). This analysis calculated a human influence index, derived from data sets of human population density, the location of built-up areas, transport infrastructure and routes, landscape transformation and power infrastructure, and it incorporates information from NASA's Earth Observing System Data and Information System (EOSDIS). These data were then compared at a biome level, to identify the 10% of each of the earth's biomes that has been least affected by human impacts (Sanderson *et al.* 2002).

> The Outback, as one of the world's largest wild and lightly populated areas, is one of the few places where conscious planning based on existing strengths could have a high likelihood of averting such a dire outcome.

The analysis reveals that there are few remaining large and largely natural areas left on Earth: the boreal forests and tundra of far North America, Siberia and Greenland; the Sahara; the rapidly diminishing wildlands of the Amazon basin; the Himalayas and Tibetan plateau; and Outback Australia (Figures 6, 7). (Note that Antarctica was not included in this study because its landmass is nearly devoid of terrestrial life.)

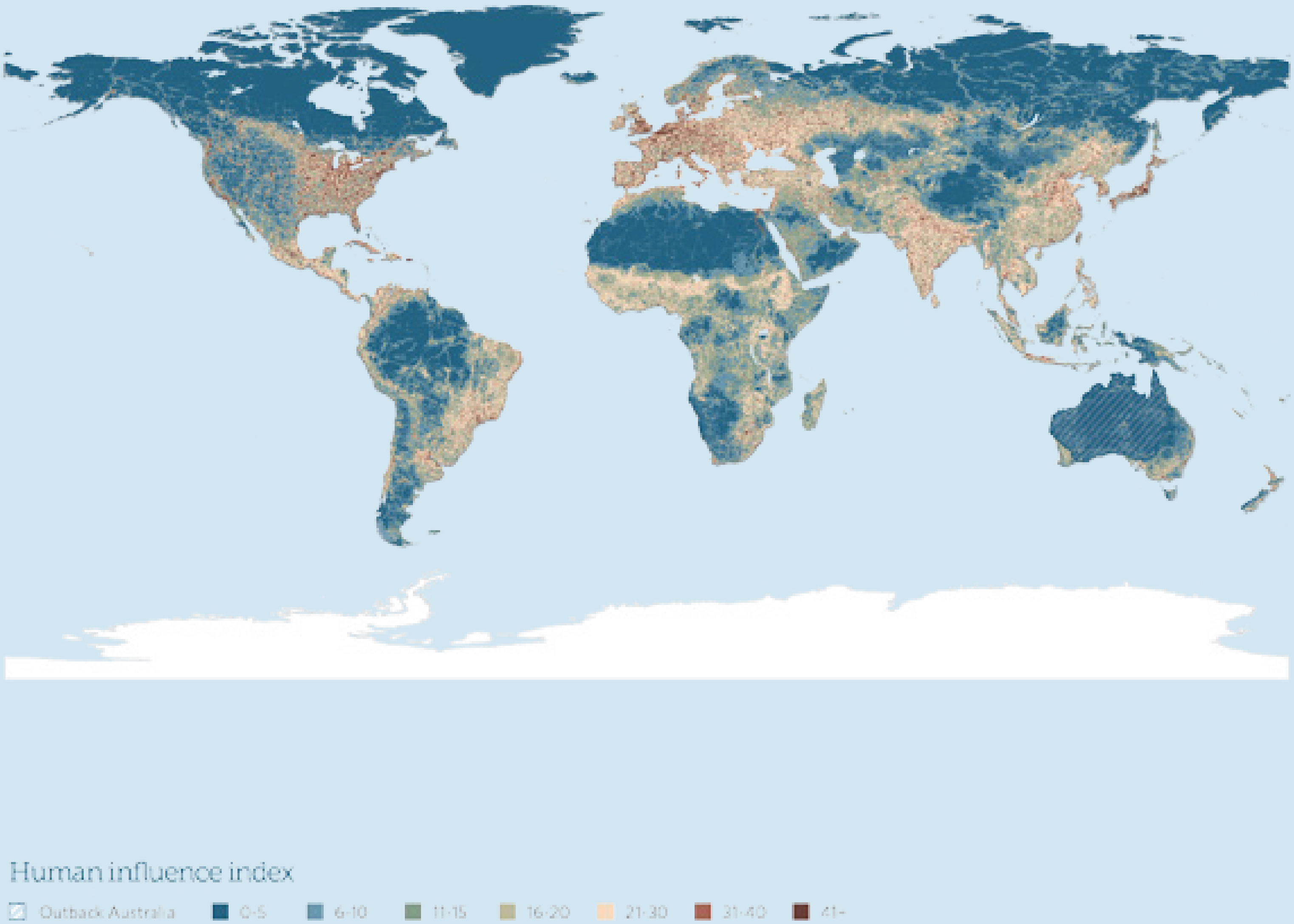
It is these areas that are most likely to provide a space for biodiversity to be sustained and to maintain the ecological processes on which that biodiversity, and we ourselves, depend.

The two main environmental components of the Australian Outback, the tropical savannas of northern Australia (Woinarski *et al.* 2007) and the desert environments of central Australia (Morton *et al.* 2011), have also been compared to similar environments elsewhere in the world. The tropical savanna comparison focused on ecological integrity and combined indices relating to clearing and cultivation, livestock density and human population density. That study concluded that almost 70% of the original global extent of 12 million km^2 of tropical savanna woodlands has been cleared and only 22% of the remaining 3.7 million km^2 has high integrity (Woinarski *et al.* 2007). By far the largest expanses of intact tropical savannas are in northern Australia (Figure 8).

Australia's more than 3 million km^2 of deserts are among the least modified in the world. The ecological patterning and functioning of Australian desert systems differ from those of other continents, having a set of distinctive ecological and evolutionary traits (Morton *et al.* 2011).

Figure 6

'Last of the Wild' Analysis: Human Influence Index



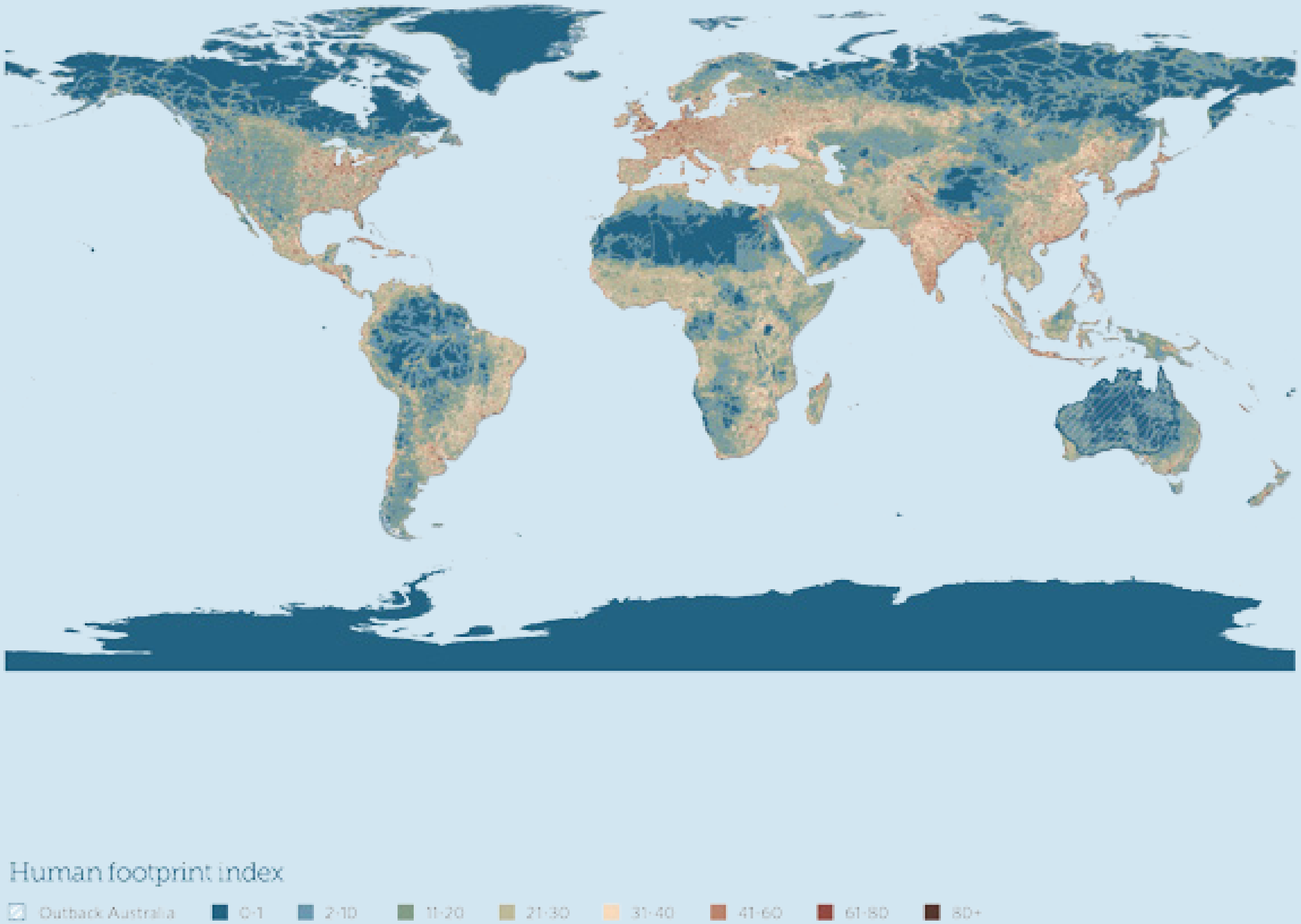
Source: Derived from Sanderson et al. (2002) and subsequent analyses

Figure design by The Pew Charitable Trusts

Figure 7

'Last of the Wild' Analysis: Human Footprint Index

Based on normalisation across biomes of the Human influence index

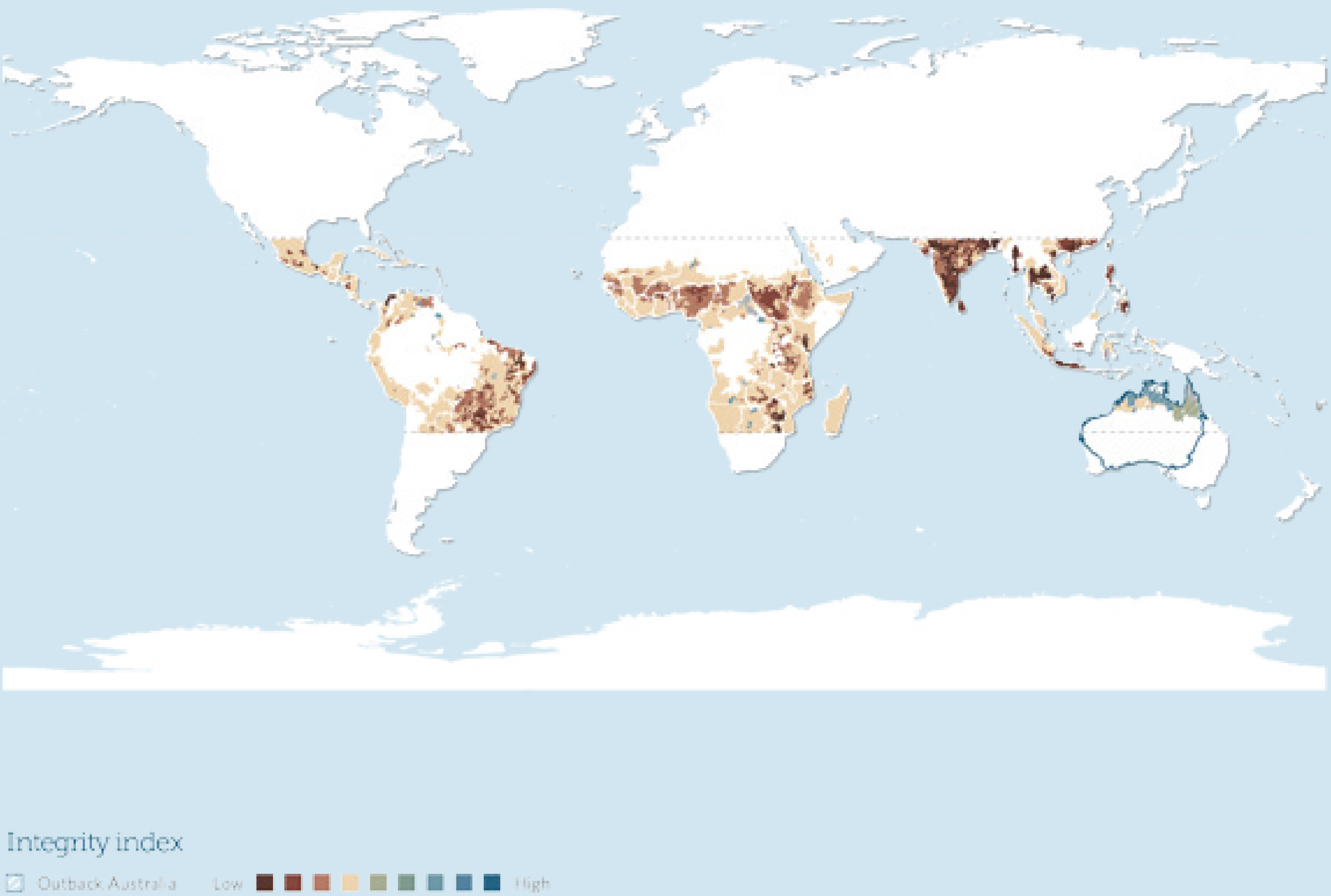


Source: Derived from Sanderson et al. (2002) and subsequent analyses

Figure design by The Pew Charitable Trusts

Figure 8

Condition and Integrity of the World's Tropical Savannas



Note: The condition of tropical savanna areas from highly modified (dark brown) to highly intact (dark blue)

Source: Woinarski et al. (2007)

Figure design by The Pew Charitable Trusts

A tourist takes in the breathtaking panorama of Jim Jim Falls and the Arnhem Land escarpment in the Northern Territory's UNESCO World Heritage-listed Kakadu National Park.

There are also significant areas of other environments in the Outback. Extending over about 160,000 km^2, the Great Western Woodlands of inland south-western Australia are now recognised to be the largest intact area of woodland habitat in the world's temperate Mediterranean climate zones – areas with cool wet winters and hot dry summers (Judd *et al.* 2008; Watson *et al.* 2008; Underwood *et al.* 2009).

The relatively intact nature of Outback woodlands is also well defined by comparisons on a national scale. There is a marked contrast between the largely intact condition of woodlands across Outback Australia and the woodlands in the more densely settled regions of Australia, which are far more likely to have been cleared or fragmented and modified (Figure 9).

Australia now has the largest remaining wild areas in the world for three global biomes: tropical and subtropical grasslands, shrublands and savannas; deserts and xeric shrublands; and Mediterranean forests, woodlands and scrub (CIESIN and WCS 2003).

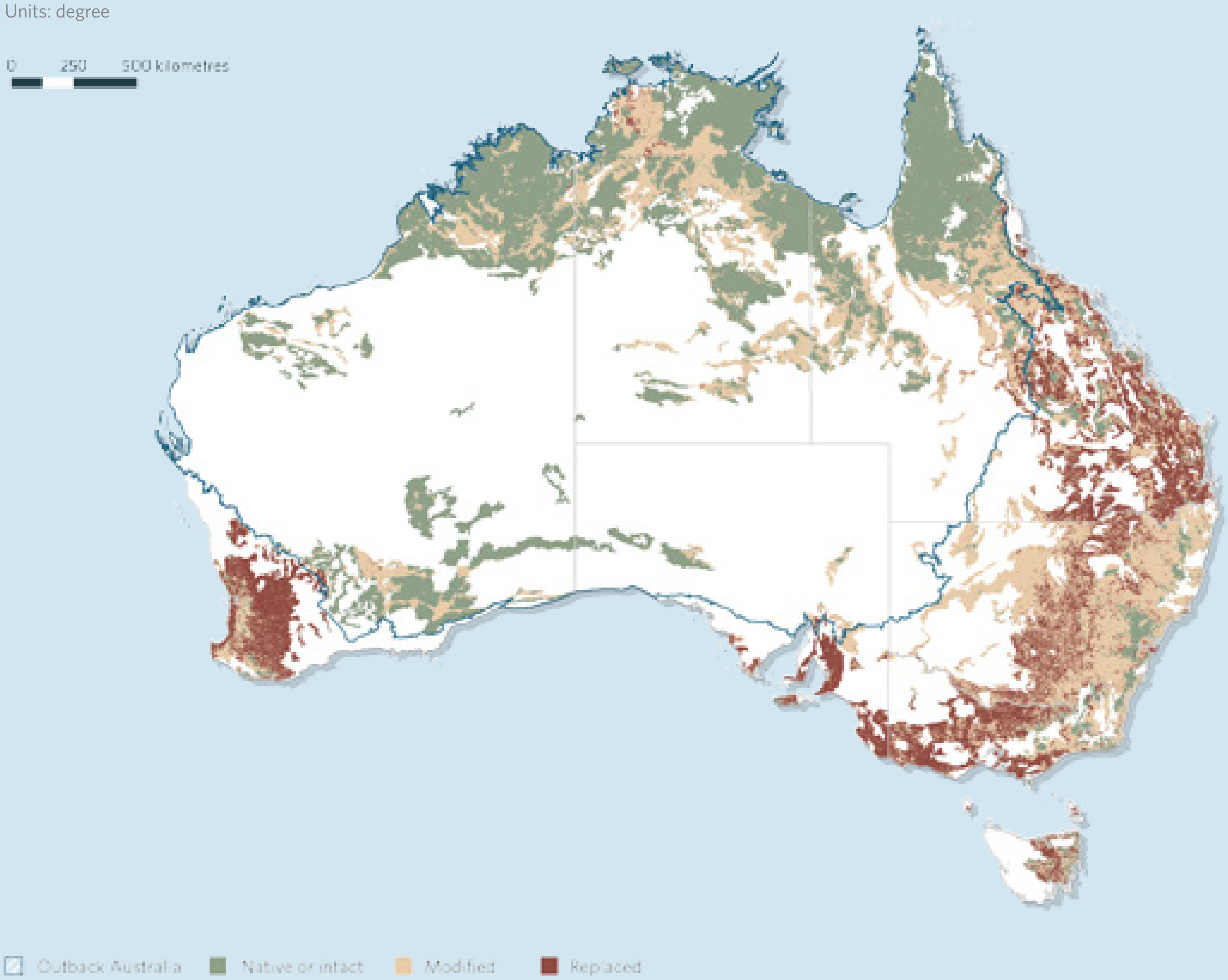
Australia's savanna woodlands, such as these in the Top End, are by far the largest expanse of healthy tropical savannas left in the world. They are also one of our planet's most flammable ecosystems.

Figure 9

Condition of Woodlands in Australia

White areas represent non-woodland habitat

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: degree



Source: Woinarski et al. (2007)

Figure design by The Pew Charitable Trusts

Much of the Australian Outback has also been recognised as being among the world's most important global wilderness areas (Figure 10). In this global comparison, wilderness areas were characterised as extensive areas with low human population and generally intact ecological systems and defined as areas larger than one million hectares, greater than 70% intact and with human densities less than 5 people/km^2 (Gil 2002; Mittermeier *et al.* 2003). The use of the term 'wilderness' with reference to the Outback is described in a little more detail in Insight 3.

The condition of, and stresses to, terrestrial environments also affect aquatic and nearby marine environments. A global assessment of threats to aquatic biodiversity similarly recognised tropical Australian aquatic systems to be among the least impacted by human activity in the world (along with the tundra and boreal regions of North America and Siberia and the Amazon) (Vörösmarty *et al.* 2010). This analysis did not evaluate the condition of the Outback's arid and semi-arid wetlands (Figure 11).

Outback rivers channel close to half of Australia's total surface run-off and include some of the world's last free-flowing and relatively pristine large river systems. Many Outback river systems are notable for their lack of dams or other modification from upper catchment to coast (Australian Tropical Rivers Group 2004; Douglas *et al.* 2005). The Lake Eyre Basin, encompassing almost one-sixth of Australia, is the world's largest internally draining system and one of the few free-flowing arid river systems remaining in the world (McMahon *et al.* 2008). Underlying much of the eastern half of the Outback, the Great Artesian Basin is the largest groundwater basin in the world (1.7 million km^2). Most of the rivers, wetlands and estuaries of northern Australia are in good ecological condition (National Land & Water Resources Audit 2002). As is the case for most terrestrial vegetation types, there is a marked contrast between the generally unmodified and healthy Outback wetland environments and the substantially transformed wetland systems in more settled areas of Australia (Figure 12; Table 3).

The relatively intact and good condition of most Outback river systems also means that estuaries around the Outback coast are also in generally good condition relative to those of more settled regions (Figure 13), and that the coastal marine systems are in unusually intact condition.

A global assessment of the condition of, and threats to, the world's marine environments (Halpern *et al.* 2008) indicated that there were very few coastal environments, other than those in polar areas, that had been relatively little affected by human activity. Many of the world's estuaries are now contaminated by excess nitrogen arising from agricultural lands and transported by rivers to the sea, where they create dead zones for marine life and fisheries (Rockström *et al.* 2009). The unpolluted state of most of the Outback's rivers combined with the high number of free-flowing rivers that make their way unimpeded to the ocean are globally significant.

Coastal waters of the north Australian Outback represent one of the few extensive areas of tropical or temperate seas subject to very low levels of human impact (Figure 14).

> Coastal waters of the north Australian Outback represent one of the few extensive areas of tropical or temperate seas subject to very low levels of human impact.

Insight 3

The Outback as wilderness

In this report, we have used the word 'wilderness' sparingly. This is because the word is commonly perceived to apply to country that is without humans or the influence of management by humans. For Aboriginal people in the Outback, that concept is almost incomprehensible and profoundly ignorant, because it severs the essential connection between people and land.

However, the term can be, and has been, widely used to describe the Australian Outback or large segments of it (Booth and Traill 2008) and is applicable with appropriate definition.

The Outback is one of the world's great remaining wilderness areas because it meets all three dimensions of the wilderness concept: biological, social and economic. It is biologically largely intact for both native species and natural processes. Socially, it is important as the home of Indigenous people who use traditional rather than industrial practises and as an iconic and valued recreational area for urbanised people who seek to escape to wild nature. And it is economically important primarily because of the ecosystem services it provides (Kormos and Locke 2008).

Table 3

The Unmodified Nature of Outback River Systems Relative to Those in More Densely Settled Regions of Australia, Indicated by the Number and Size of Impoundments (Dams)

River basins	Mean annual run-off (megalitres)	Number of dams (>10 m high)	Storage capacity as % of mean annual flow	% of divertible flow taken for human use
Outback river basins				
Timor Sea	80 700 000	9	8	9
Gulf of Carpentaria	92 500 000	8	1	1
Lake Eyre	6 310 000	2	0	13
Bulloo-Bancannia	1 090 000	0	0	0
Western Plateau	1 580 000	1	0	0
Indian Ocean	3 960 000	2	2	0
River basins in intensive use zone				
North-east coast	83 900 000	63	11	16
South-east coast	41 900 000	128	32	28
Tasmania	52 900 000	70	62	9
Murray-Darling	24 300 000	107	103	81
South Australian Gulf	877 000	25	30	44
South-west Coast	6 670 000	31	16	13

Source: Kingsford 2000, Pusey and Kennard 2009

Table design by The Pew Charitable Trusts

Figure 10

The Map of the World Wilderness Areas

Source: Mittermeier et al. 2003 Reproduced with permission: Copyright (2003) National Academy of Sciences, USA

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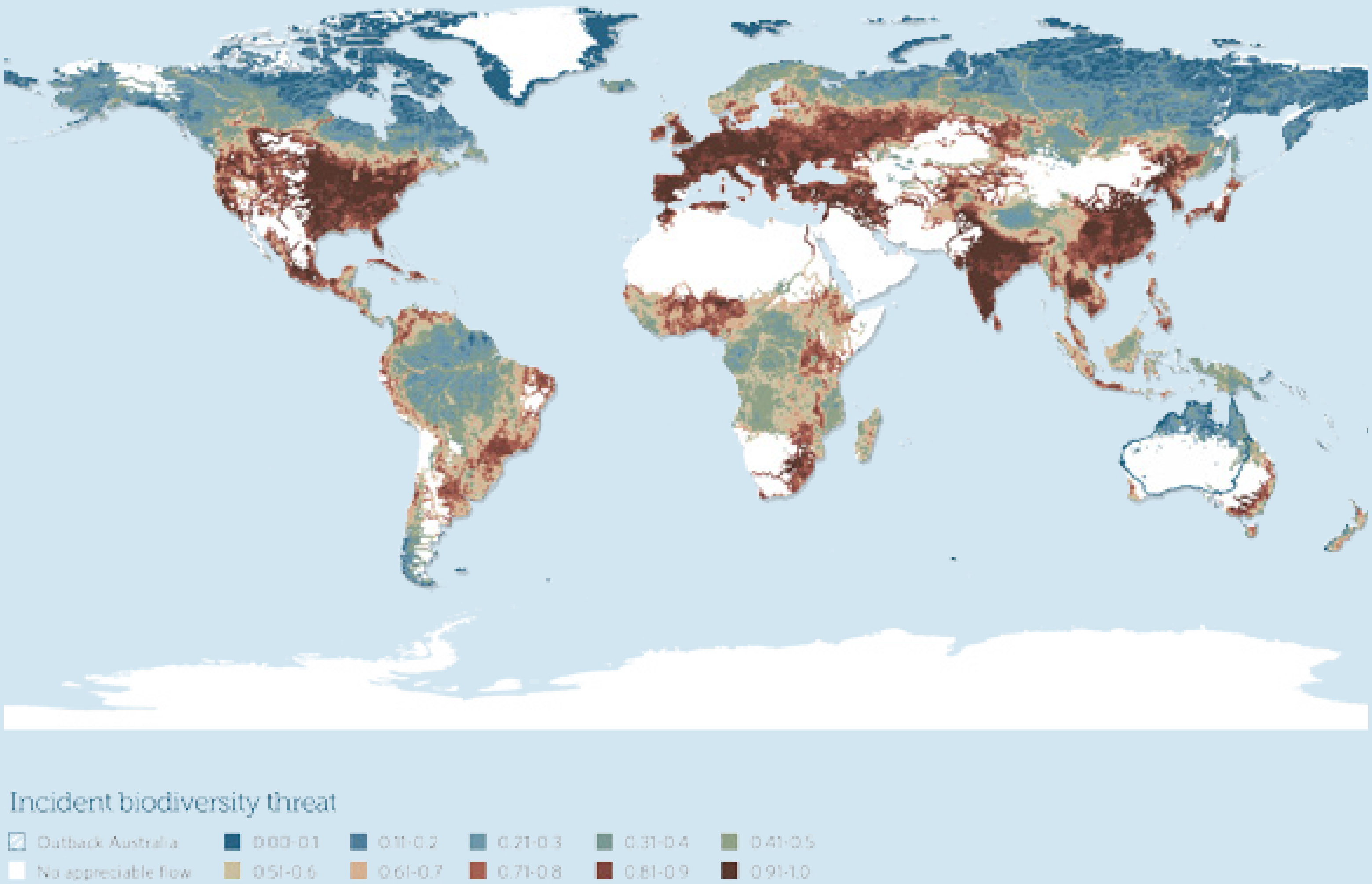
Figure 11

Extent of Threats and Their Impact on Aquatic Biodiversity

Impacts ranging from least (blue) to most (brown)



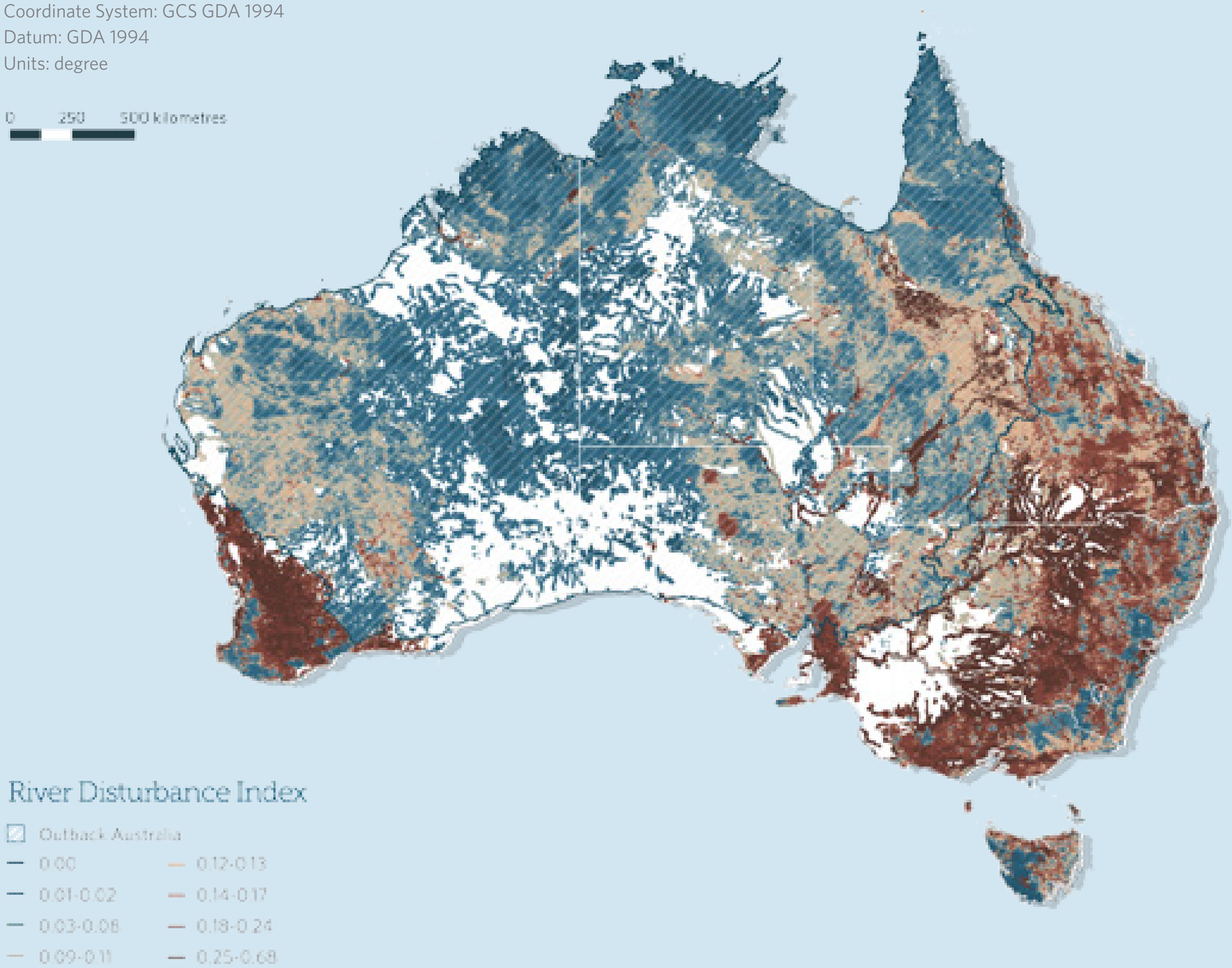
Source: Vörösmarty et al. (2010)

Figure design by The Pew Charitable Trusts

Figure 12

River Disturbance Index

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: degree



Note: Dark blue signifies rivers and catchments that have high levels of integrity. Dark brown signifies rivers and catchments that are highly altered and disturbed by humans, including impoundment and water diversification and degradation.

Source: Derived from Stein et al. (2002); Stein et al. (2014)

Figure design by The Pew Charitable Trusts

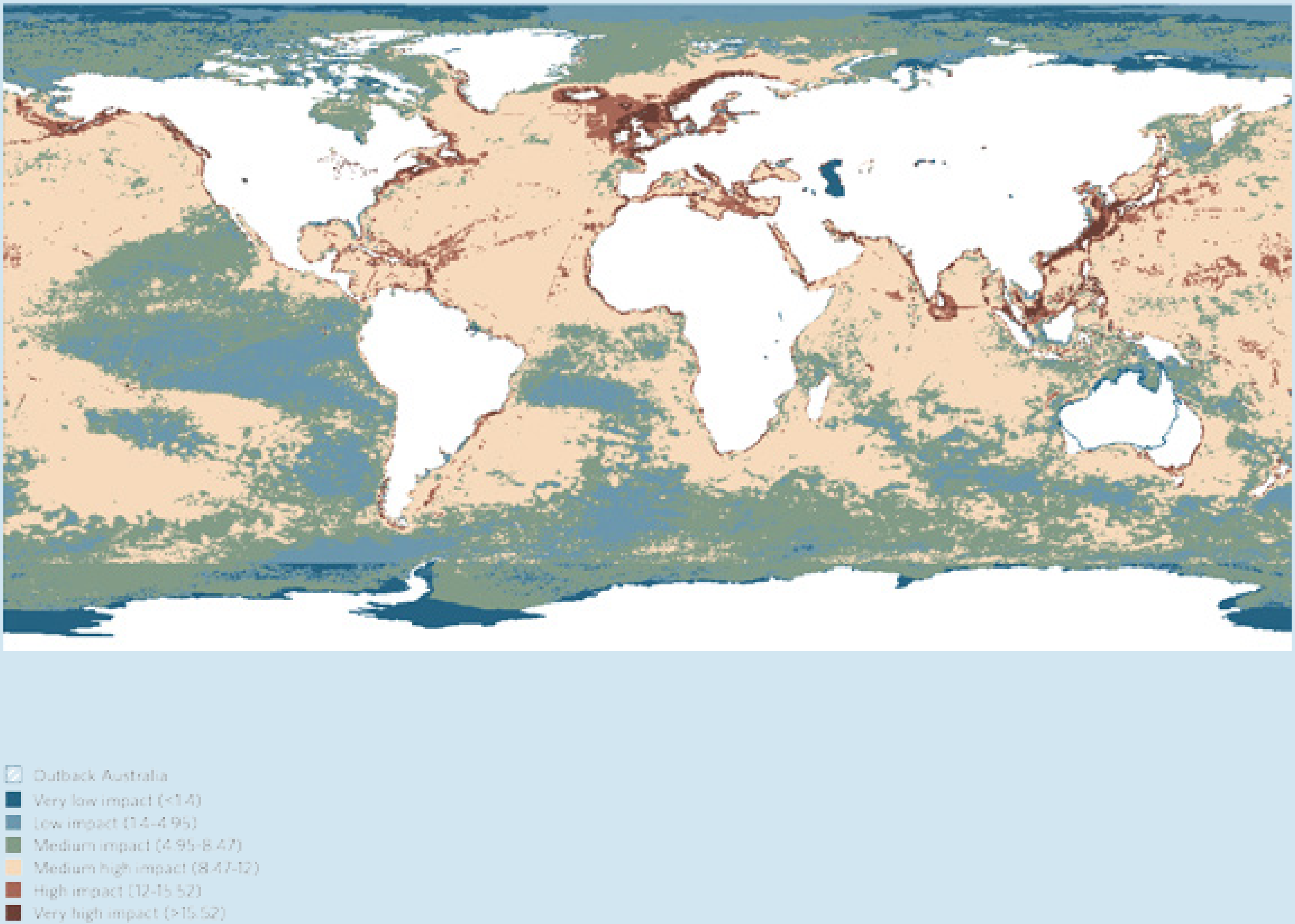
Figure 13
Condition of Australian Estuaries

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: degree

Source: Geoscience Australia (Heap et al. 2001, National Land & Water Resources Audit 2002)

Figure design by The Pew Charitable Trusts

Figure 14
Human Impact on the World's Marine Ecosystems



Source: From Halpern et al. 2008, 'A Global Map of Human Impact on Marine Ecosystems', *Science* 319, 948–952 Reprinted with permission of the American Association for the Advancement of Science (AAAS)

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Figure design by The Pew Charitable Trusts

3.2. Diversity and distinctiveness

Assessing global conservation significance and priority is not straightforward, and many different approaches are used worldwide (see Spotlight 2). These place varying emphases on biodiversity richness, endemism, the degree of current and projected threats, intactness, likelihood of maintaining ecological processes, conservation representation, ecosystem services and cost. Results differ markedly depending on how these factors are weighted and on nuances of the questions asked. The preceding analyses identified those parts of the world that have remained the most natural and least modified by human activities. In the following analyses we also consider some additional biodiversity attributes.

The global ecoregions approach of the World Wildlife Fund (WWF) (https://www.worldwildlife.org/biomes) has sought to identify and rank the Earth's most biologically outstanding representatives of every major ecoregion (terrestrial, freshwater and marine), with selection filtered to represent every biogeographic realm and ocean basin, and 'ecoregion' defined as a 'large unit of land or water containing a geographically distinct assemblage of species, natural communities, and environmental conditions' (Olson *et al.* 2001; Olson and Dinerstein 2002). The valuation of 'biologically outstanding' included consideration of species richness, endemism (the restriction of species to a particular area), taxonomic distinctiveness, global rarity of habitats and extraordinary ecological and evolutionary phenomena. Much of the Outback is included among the 200 globally significant ecoregions, within the Northern Australia and Trans-Fly Savannas, the Carnarvon Xeric Scrub, the Great Sandy – Tanami Deserts terrestrial ecoregions (Figure 15), and the Kimberley Rivers and Streams and Central Australian Freshwater aquatic ecoregions.

Consistent with it covering most of the continent, the Outback possesses the general features that make Australian environments and biodiversity so distinctive, special and important (Figure 16). Australian plants and animals are notably evolutionarily distinct from those of other continents and include many of the most ancient groups of plant and animal life (Isaac *et al.* 2007; Holt *et al.* 2013). The distinctiveness of these plant and animal species is globally significant. For example, more than 80% of Australia's mammals, reptiles, frogs and plants, and about 70% of its insects, occur nowhere else (Chapman 2009).

Australia is also recognised as one of 17 'megadiverse' countries – those with exceptional biodiversity – and is one of only two developed countries considered to be megadiverse (Mittermeier *et al.* 1997). Of an estimated 11 million species worldwide, about 570,000 are native to Australia (Chapman 2009).

> Australian plants and animals are notably evolutionarily distinct from those of other continents and include many of the most ancient groups of plant and animal life.

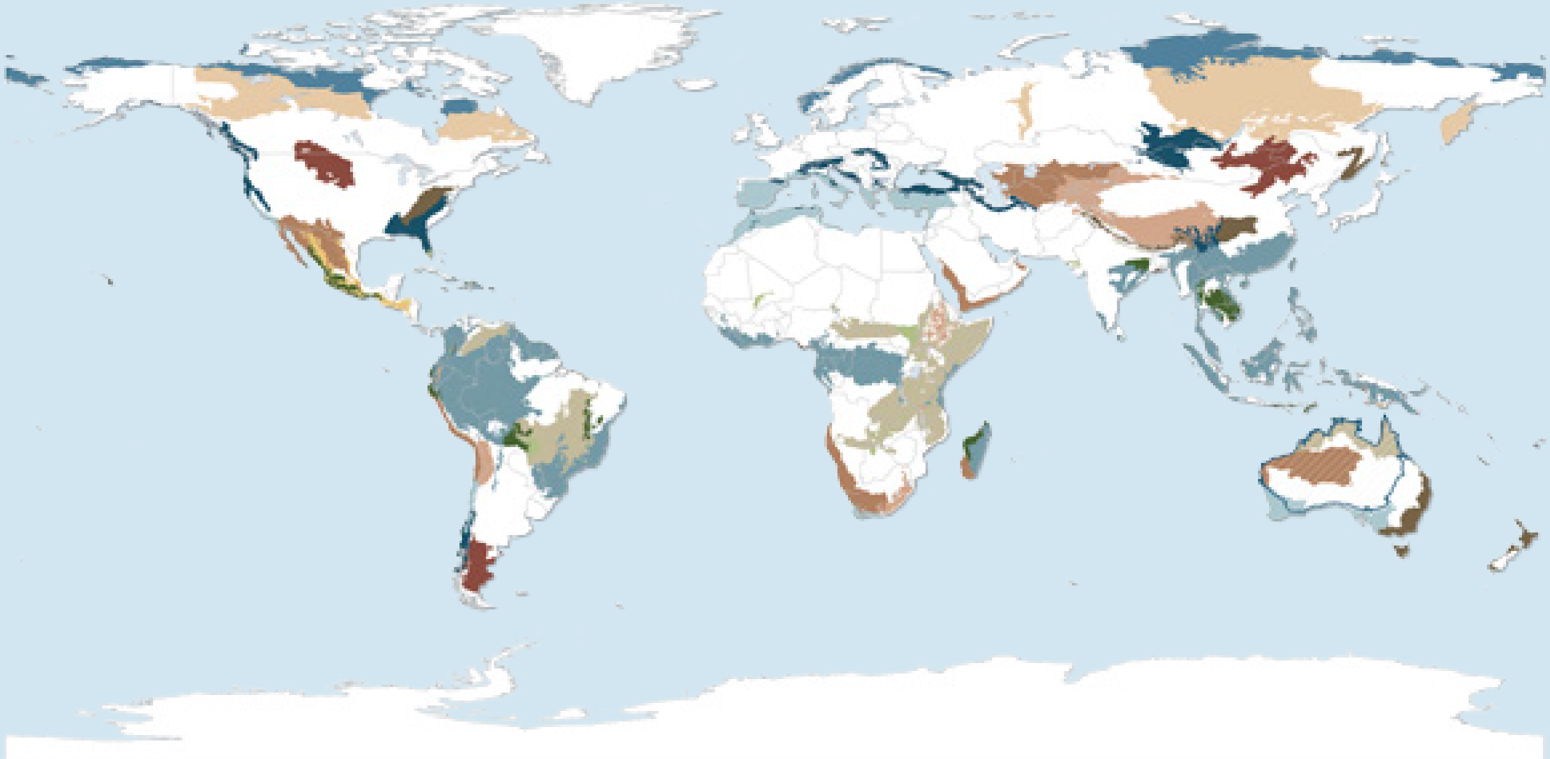
The Outback's natural values are not simply a subset of Australian natural values. Some Australian environments and species are not present in the Outback, and some Outback environments and species are not found in the rest of the continent. Of shared environments and species, some are better represented, or have persisted better, in the Outback. Of significant Australian environments, the Outback has limited or no representation of alpine areas, cool temperate and subtropical rainforests, wet sclerophyll (tall eucalypt) forests and temperate heathlands. The core area of tropical rainforests (the Wet Tropics) also lies outside the Outback, but there are significant rainforest formations in the Outback, most notably in Cape York Peninsula (particularly the Iron and McIlwraith Ranges) and in coastal and higher rainfall areas of the Top End and Kimberley. Conversely, the Outback has all or most of Australia's desert environments (hummock grasslands), tropical savannas, mangroves, *Acacia* formations, chenopod shrublands, tropical heathlands and floodplains. There is a more even distribution between Outback and non-Outback areas for tussock grasslands and temperate woodlands (for the Outback, most notably in the Great Western Woodlands), and the number of Australia's many islands is also broadly similar off Outback and non-Outback coasts.

Particular sites in the Outback are also recognised internationally for their biodiversity significance. Six Outback areas are listed as World Heritage sites based on their natural – and in some cases also on their cultural – values: Kakadu, Purnululu, Riversleigh (part of Australian Fossil Mammal sites), Shark Bay, the Ningaloo Coast and Uluṟu–Kata Tjuṯa. At least one other site, Cape York Peninsula, is considered to meet the World Heritage criteria (Hitchcock *et al.* 2013), but has not yet been nominated.

Eight areas in the Outback are listed as Ramsar sites, or wetlands of international importance: Cobourg Peninsula, Kakadu, Ord River Floodplain, Lakes Argyle and Kununurra, Roebuck Bay, Eighty Mile Beach, Coongie Lakes and Lake Pinaroo (Fort Grey Basin). Many other Outback wetlands are likely to meet the Ramsar eligibility criteria. Many of these Ramsar wetlands are critical sites because a significant proportion of the global population of many intercontinental migratory shorebird species congregates in these locations for part of their annual migratory cycle. For example Eighty Mile Beach, near Broome in the south-west Kimberley,

Figure 15

WWF's Global Priority Ecoregions: Terrestrial



Terrestrial major habitat types

- Outback Australia
- Temperate coniferous forests
- Boreal forests/Taiga
- Tundra
- Temperate broadleaf & mixed forests
- Tropical & subtropical moist broadleaf forests
- Flooded grasslands & savannas
- Tropical & subtropical coniferous forests
- Tropical & subtropical dry broadleaf forests
- Tropical & subtropical grasslands, savannas & shrublands
- Temperate grasslands, savannas & shrublands
- Montane grasslands & shrublands
- Deserts & xeric shrublands
- Mediterranean forests, woodlands & scrub
- Mangroves

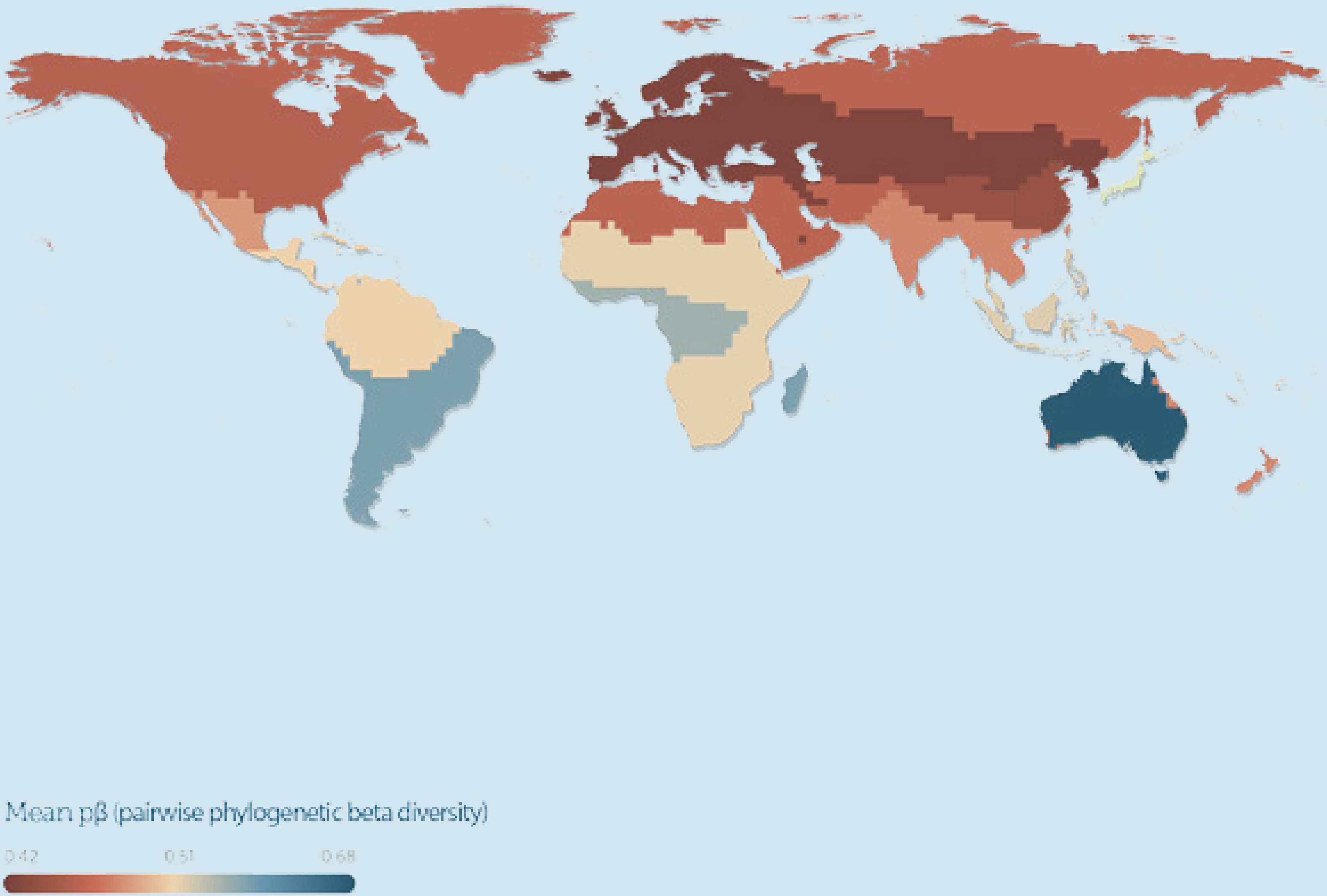
Note that different colours simply represent different biomes, but all coloured areas are considered to be priority ecoregions.

Source: Olson and Dinerstein 2002

Figure design by The Pew Charitable Trusts

Figure 16

Evolutionary Distinctiveness of the World's Vertebrates



Note: Darker colours indicate that the fauna is more distinct – i.e., most unlike that found elsewhere.

Source: Holt et al. 2013, 'An update of Wallace's zoogeographic regions of the World', *Science* 339, 74–78

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Figure design by The Pew Charitable Trusts

regularly contains 400,000 – and at times over a million – migratory shorebirds. Decades of research at this site and nearby Roebuck Bay have been pivotal in understanding the biology and conservation requirements of many species of migratory shorebirds (Minton 2006). Well over a hundred Outback sites are also recognised as globally Important Bird Areas (Dutson *et al.* 2009).

These sites represent some of the Outback's jewels, but their value and resilience also depend on the fate and condition of their surrounds. It is the integrity of the whole landscape in which these sites are set that is of pre-eminent significance.

3.3. Ecosystem services

The intact terrestrial and wetland systems of the Outback and its coasts provide many ecosystem services that are important at regional and national levels. These include the provision of drinking water, the supply of harvested food resources (such as fish), the resource base for many industries (most notably in the Outback, extensive cattle production), and the maintenance of many cultural values.

The intact Outback environments are also becoming increasingly important internationally for their role in carbon storage and their potential to mitigate carbon emissions. Notwithstanding the generally low biomass of vegetation at any site in the Outback, the extensive nature of the Outback means that even small amounts of carbon storage per hectare aggregate to significant totals. Analysis by the Queensland Herbarium concluded that about 9.8 billion tonnes of carbon are sequestered in the vegetation of the Outback (The Nous Group 2010). For context, in 2012 Australia's greenhouse gas emissions from all sources were about 550 million tonnes. Improved land management practices – such as promoting vegetation regrowth and enhancing the management of fire, livestock and feral animals – have the potential to increase the Outback's carbon storage by slightly more than a billion tonnes (Fensham and Guymer 2009; The Nous Group 2010). Such enhanced management can also reduce greenhouse gas emissions by 30 million to 40 million tonnes per year in perpetuity (The Nous Group 2010).

The Bungle Bungle Range in northern Western Australia features distinctive beehive-like sandstone mounds and supports vegetation ranging from desert shrubs to riparian closed forest. The area, part of Purnululu National Park, was declared a World Heritage site in 2003 for its incomparable natural values.

Spotlight 2 **Assessing global conservation priorities**

The accelerating rate of biodiversity loss, and of pressures affecting biodiversity, has prompted a series of collaborative international commitments to biodiversity protection (notably including the Aichi targets of the International Union for Conservation of Nature (IUCN)). The inability of current conservation efforts to keep pace with the rate of decline has also led to a series of approaches aimed at prioritising conservation action, with most of these approaches now including specific spatial prioritisations, facilitated by increasingly comprehensive global data sets for biodiversity, conservation reserves and threats.

One approach focuses on species and the most efficient conservation allocation to ensure protection for those species that are currently unreserved or inadequately reserved. One analysis considered the world's vertebrates (Rodrigues *et al.* 2004) and heavily weighted species richness and centres of endemism, generally prioritising sites in the tropics and in areas with relatively low levels of current reservation. The Outback is not considered a priority in this analysis, largely because a relatively high proportion of its vertebrate species are included in conservation reserves.

Many other prioritisation processes for global conservation have been developed. As an example of the diverse, and at times contradictory, protocols, one study reported on the characteristics of 21 different conservation prioritisation approaches being implemented by 13 different conservation organisations (Redford *et al.* 2003). These included 12 approaches that addressed the question of where to direct conservation actions and nine approaches on how to apply conservation actions. These different conservation prioritisation approaches are built on, and respond to, different underlying principles, mostly relating to: representation – prioritisation should be directed to sites and species that are poorly reserved; efficiency – with finite resources, priority areas are those that deliver conservation targets most efficiently; and functionality – prioritisation should relate to the longer-term resilience of conserved sites.

To some extent, there is crossover between some of these approaches. For example, the world's major wilderness areas include those areas that are mostly likely to maintain ecological processes but do not necessarily contain many endemic species, and hence do not necessarily contribute substantially to an objective of protecting, in the short term, all of the world's species. However, a subset of high-biodiversity wilderness areas can be identified and such sites may contribute most to the long-term maintenance of the world's biodiversity (Mittermeier *et al.* 2003).

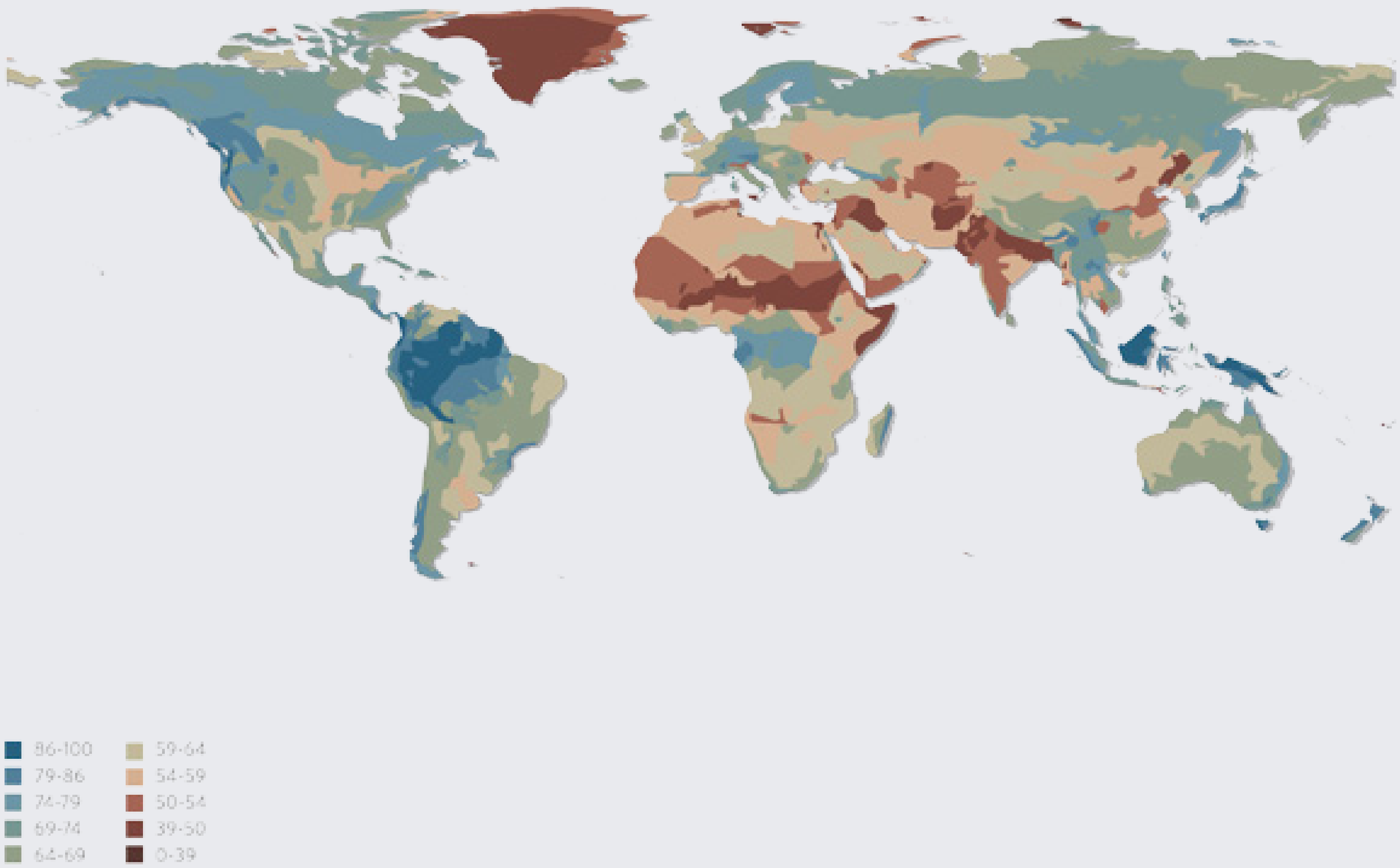
Nine major approaches have been used in global conservation prioritisation (Brooks *et al.* 2006). Most incorporate – or focus narrowly on – 'irreplaceability': places that support many species or environments not found elsewhere. However, some approaches – such as hot spots – prioritise sites with high vulnerability whereas others – such as wilderness areas –prioritise areas without such major threats. The former approach has been termed reactive and the latter proactive (Brooks *et al.* 2006) and they result in very different conservation prioritisations. Reactive approaches may identify the most urgent priorities for conservation action, because there is a high risk of loss of biodiversity if no action is taken, however the proactive approaches offer considerable opportunities for conservation and may provide greater long-term and large-scale security – 'biodiversity conservation clearly needs both approaches' (Brooks *et al.* 2006).

Other recent analyses add to these global conservation approaches by prioritising environments according to their provision of environmental goods and services (Chan *et al.* 2006; Naidoo *et al.* 2008) and by the extent to which natural water flows have been disrupted (Vörösmarty *et al.* 2010).

Recent prioritisation approaches have attempted to integrate ecosystem function and a series of socio-economic and viability factors. One recent study considered ecosystem functionality – particularly carbon sequestration – and the likelihood of its maintenance, socio-economic risks and constraints – with higher weightings given to regions likely to provide political and social conditions favourable to conservation – and the likelihood of the environment being secure or at risk from climate change (Freudenberger *et al.* 2013). This analysis provided a 'Last of the Functional' prioritisation and claimed to 'represent a shift in thinking and practice away from traditional values of conservation towards the implementation of effective large-scale conservation areas that are designed to function naturally and to provide resilience to the impacts of climate change' (Freudenberger *et al.* 2013). That analysis placed the Outback as relatively mid-range in prioritisation, behind such areas as the boreal forests – which scored more highly largely because of their greater potential for sequestration – the Amazon Basin, New Guinea, Borneo, Scandinavia, Japan and New Zealand (Figure 17).

Figure 17

Global Conservation Priorities Including Consideration of Ecosystem Services, Socio-economic Factors and Likely Resilience to Climate Change



Note: Brown colours indicate lower priorities and darker blue represents higher priorities.

Source: Freudenberger et al. 2013, 'Nature conservation: priority-setting needs a global change'; *Biodiversity and Conservation* 22, 1255–1281

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Figure design by The Pew Charitable Trusts

The vast Pilbara region in Western Australia contains some of the oldest rocks in the world, as well as some of the oldest evidence of life on Earth. The Pilbara Craton was laid down 3.5–2.5 billion years ago.

4. The Outback character: lands, climate and environments

The characteristics of the natural environments of the Outback, and its present-day economy, are built on the foundations of its physical geography and climate. The Outback we see today is a place fashioned by a very long history, with some turbulent periods but with generally less rapid and dramatic change than in most parts of the world. Aspects of its fabric would be different 50 years ago, 1000 years ago, 10,000 years ago, and more markedly so into deeper time as climates have oscillated, the continent drifted, landforms changed, and humans entered and became part of the landscape. Although the stories are fascinating, we will focus (briefly) on those historic events most critical to the modern appearance and function of the Outback landscapes. This section relates to physical and natural environments. Human history and current social and economic characteristics of the Outback are considered in a subsequent section.

The Outback's physical setting and history are largely that of Australia as a whole. Long geological stability, eons of weathering and a turbulent climate history have rendered most of Australia flat, infertile and dry. It is the flattest of all continents. It also has the highest proportion of nutrient-poor soils and the most variable and lowest water flows of inhabited continents (Finlayson and McMahon 1991; Orians and Milewski 2007).

> Long geological stability, eons of weathering and a turbulent climate history have rendered most of Australia flat, infertile and dry.

4.1. Landforms

Much of the Earth's surface has been regularly reshaped and replenished by episodes of glaciation or volcanism. But the Outback is an extremely old and tectonically stable landform and there has been little or no such dramatic change over many million years. The important building blocks, or tectonic core, of the Pilbara, Gawler and south-western Australia were established in deep time, more than three billion years ago.

The Outback has spectacular rugged ranges, but weathering over long ages has worn them down and the highest Outback peak, Mount Zeil in the West MacDonnell Ranges, is only 1531 metres high (Figure 18). Much of the eastern Outback has little topographic variation and the lowest elevation is Lake Eyre, which lies 15 metres below sea level.

Australia's isolation has been longstanding, with a split from the supercontinent of Gondwana about 65 million years ago. The subsequent period of long isolation has been pivotal in the evolution of Australia's biodiversity, most markedly so in its high rate of endemism (the restriction of species to a particular area). However, the continental shape and proximity to other landmasses have changed over long periods. One notable example relevant to the Outback is the changing northern shoreline, which repeatedly encompassed New Guinea and the far eastern islands of present-day Indonesia, until the most recent loss of connection with rising sea levels about 6000 years ago.

Over millions of years of geological stability and limited glaciation, most Australian soils have been leached of nitrogen, phosphorus and other nutrients essential to life, such as manganese and zinc. Infertility is therefore a key feature of the Australian Outback, its ecology and its land use capability. But soils across the Outback also show some notable diversity, including cracking clays, strongly weathered red earths (kandosols) and extensive sandy dunefields (mostly linear and longitudinal).

4.2 Climate

The current climate of the Outback is marked by two major features: a relatively regular annual monsoonal (wet-dry) influence across northern Australia and the far more erratic rainfall of central Australia, where spells of dry years are punctuated by irregular major rainfall events. Average annual rainfall in the Outback is highest in the north and rapidly decreases inland. An irregular ring of semi-arid areas surrounds the arid centre of the continent (Figure 19).

As throughout Australia, the rainfall variability is magnified by the El Niño–Southern Oscillation phenomenon (Chiew *et al.* 1988), which changes sea-surface temperatures in the Pacific Ocean that profoundly affect rainfall patterning in neighbouring areas. Very wet and very dry periods associated with El Niña and La Niño, respectively, occur on average (though not regularly) every four to eight years. The between-year climatic variability of Australian arid areas exceeds that of most of the world's desert regions (Morton *et al.* 2011), and much of the ecology of central Australia is driven by the need to survive long periods of low rainfall and to capitalise on infrequent rainfall events (Figure 20, 21).

Remote Mitchell Falls in full flood, Kimberley region. The northern summer wet season brings dramatic changes to the tropical savannas and wetlands.

Figure 18

Elevational Variation Across Australia

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: degree

0 250 500 kilometres

Elevation

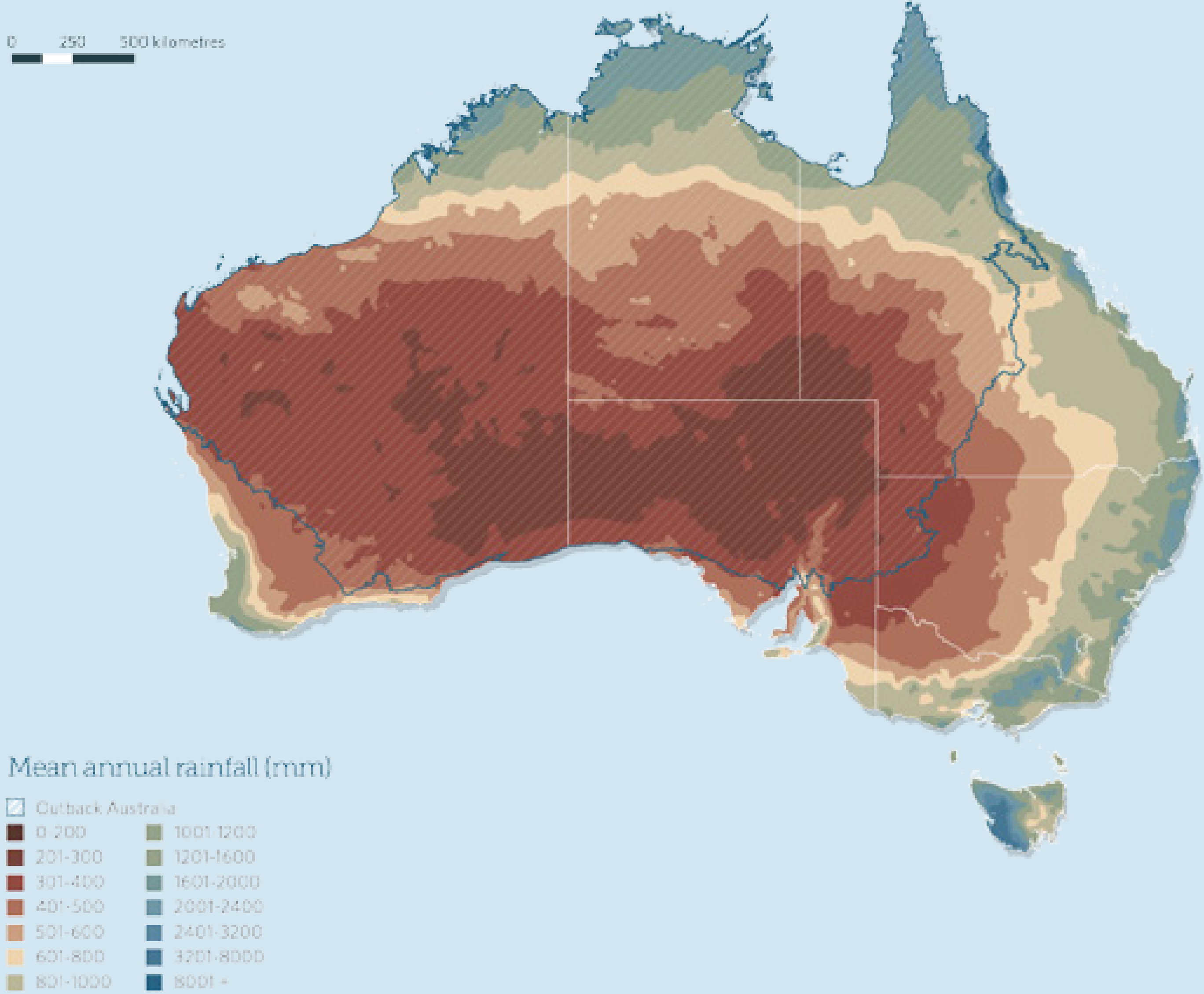
- Outback Australia
- 0-250 m
- 250-500 m
- 500-750 m
- 750-1000 m
- Greaterthan 1000 m

Figure design by The Pew Charitable Trusts

Figure 19

Average Annual Rainfall Across Australia

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: degree



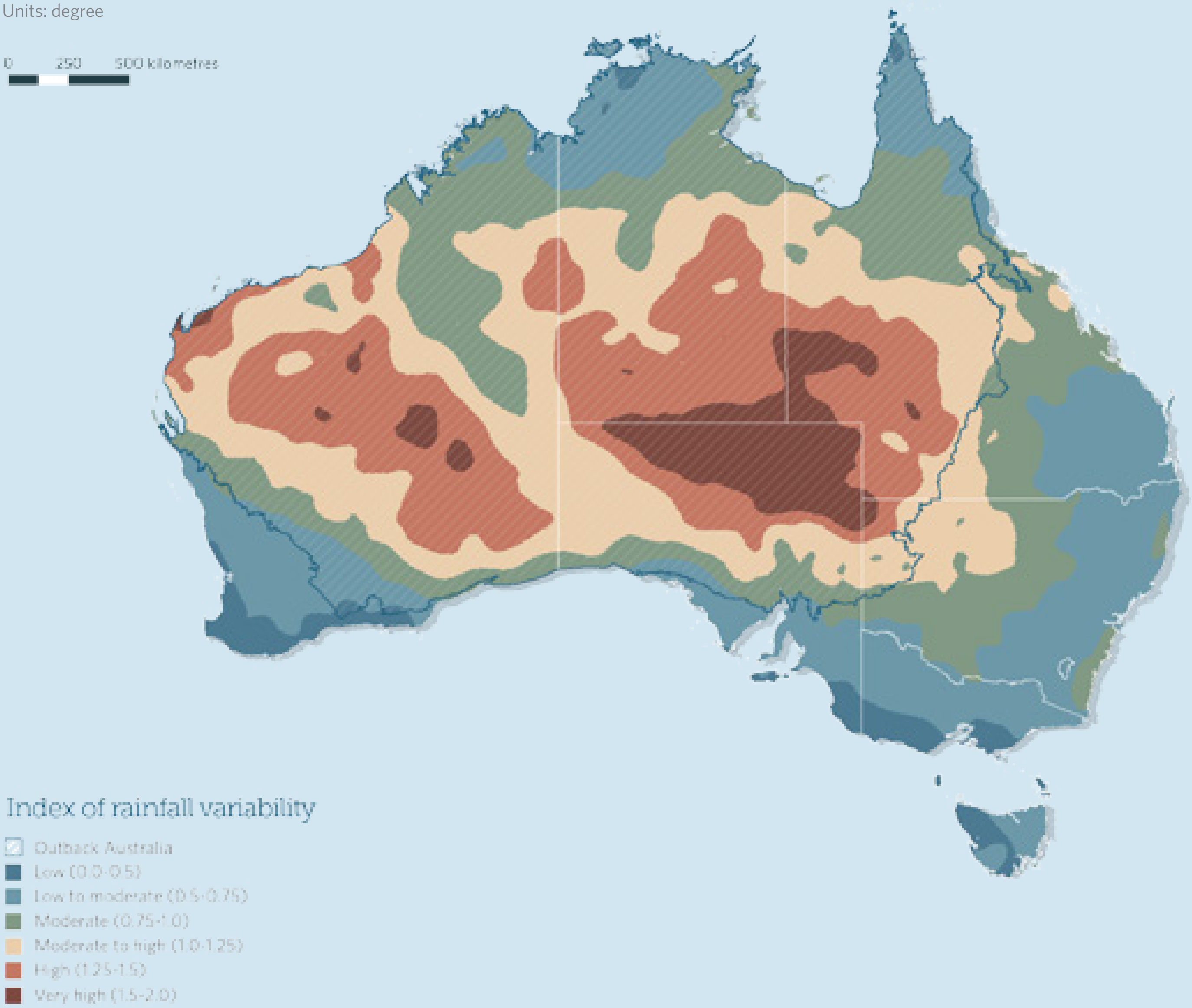
Source: Bureau of Meteorology

Figure design by The Pew Charitable Trusts

Figure 20

Between-year Variation in Annual Rainfall Across Australia

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: degree



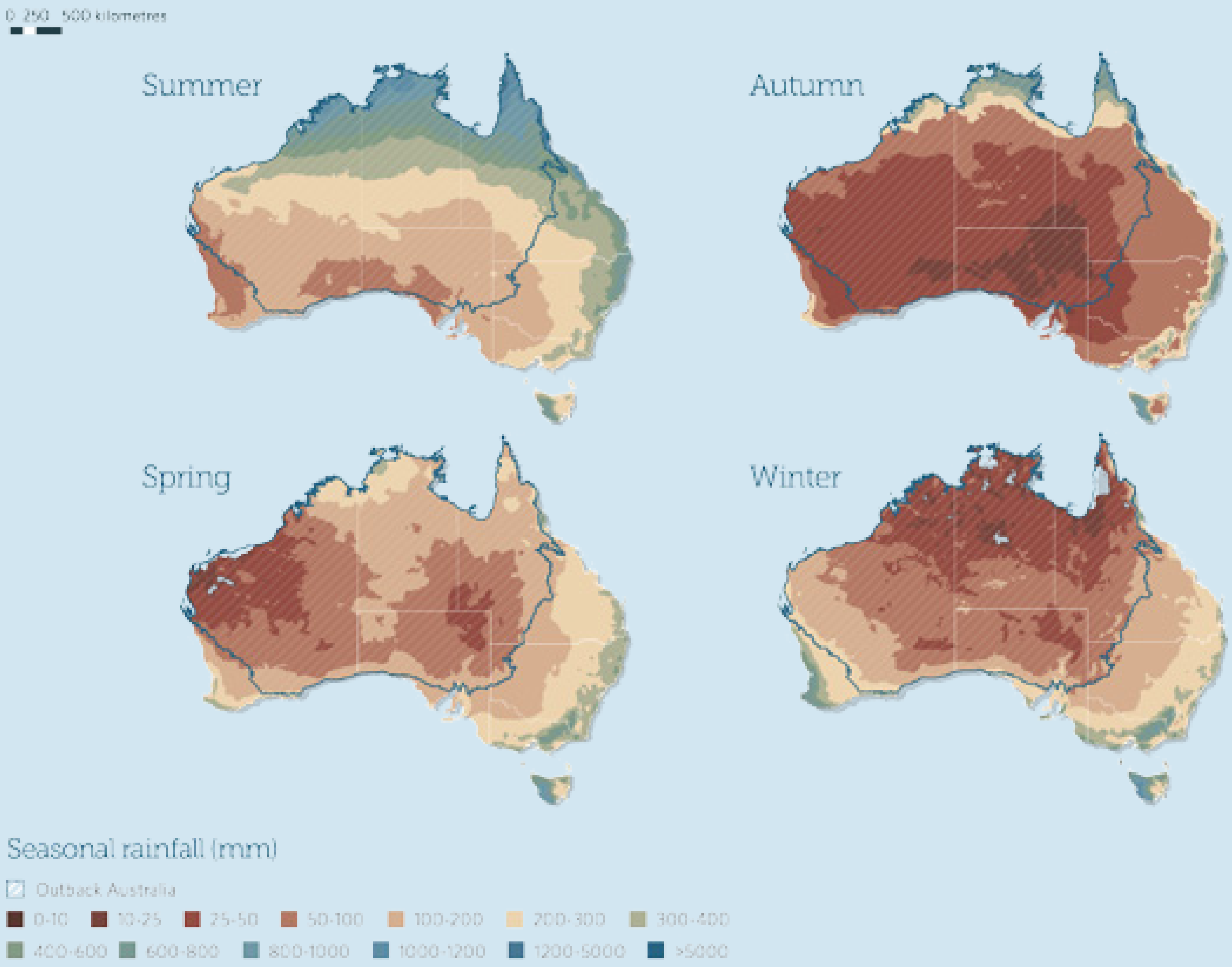
Source: Bureau of Meteorology

Figure design by The Pew Charitable Trusts

Figure 21

Rainfall Seasonality Across Australia

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: degree



Source: Bureau of Meteorology

Figure design by The Pew Charitable Trusts

In contrast, within-year climatic variability (seasonality) is more marked in monsoonal northern Australia (Figure 21, 22), with this seasonality more extreme than elsewhere in Australia or in most of the world's other monsoonal tropical areas (Cook and Mordelet 1997). Rainfall over monsoonal northern Australia 'is immense (approximately one million gigalitres annually)' (Kennard 2010). Temperatures are high year-round in northern Australia and even higher – but more seasonal – in the arid centre. Accordingly, evapotranspiration rates are typically high.

These climatic features have been longstanding, but have also varied substantially across time. The aridification of the continent began around 15 million years ago, but fully arid landforms in central Australia appeared much later, one million to four million years ago. The last 800,000 years have seen major fluctuations of the arid zone, with large areas covered by mobile sand dunes during the driest periods (Byrne *et al.* 2008). The more recent history includes cycles of more humid global interglacial and arid glacial periods, with the last global glacial maximum (about 20,000 years ago, when polar ice caps were at their maximum) being especially dry (Morton *et al.* 2011). The climate of central Australia has fluctuated since that extreme, with the most recent very low rainfall period occurring 3000 to 1500 years ago (Smith and Ross 2008; Smith *et al.* 2008).

Within the Outback, historic climate changes have resulted in some major environmental reconfigurations, most notably in the extent of central Australian dunefields and the extent and permanence of large wetland features, including the Lake Eyre system, the Willandra Lakes system, Lake Gregory and Lake Woods (Figure 24).

For northern Australia, climatic seasonality driven by the monsoon has been a largely enduring feature since the late Eocene or early Oligocene epochs (40 to 30 million years ago): 'it is likely that a monsoon climate generally similar to that of the modern day has prevailed for an enormously long period of time in northern Australia' (Bowman *et al.* 2010a). Three defining and interlinked ecological factors of Australia's northern savannas – the vegetation structure (sparse tree cover over a ground layer of grasses), the wet-dry monsoonal climate, and frequent fire – have been dated to at least five million years ago (Williams *et al.* 2009b).

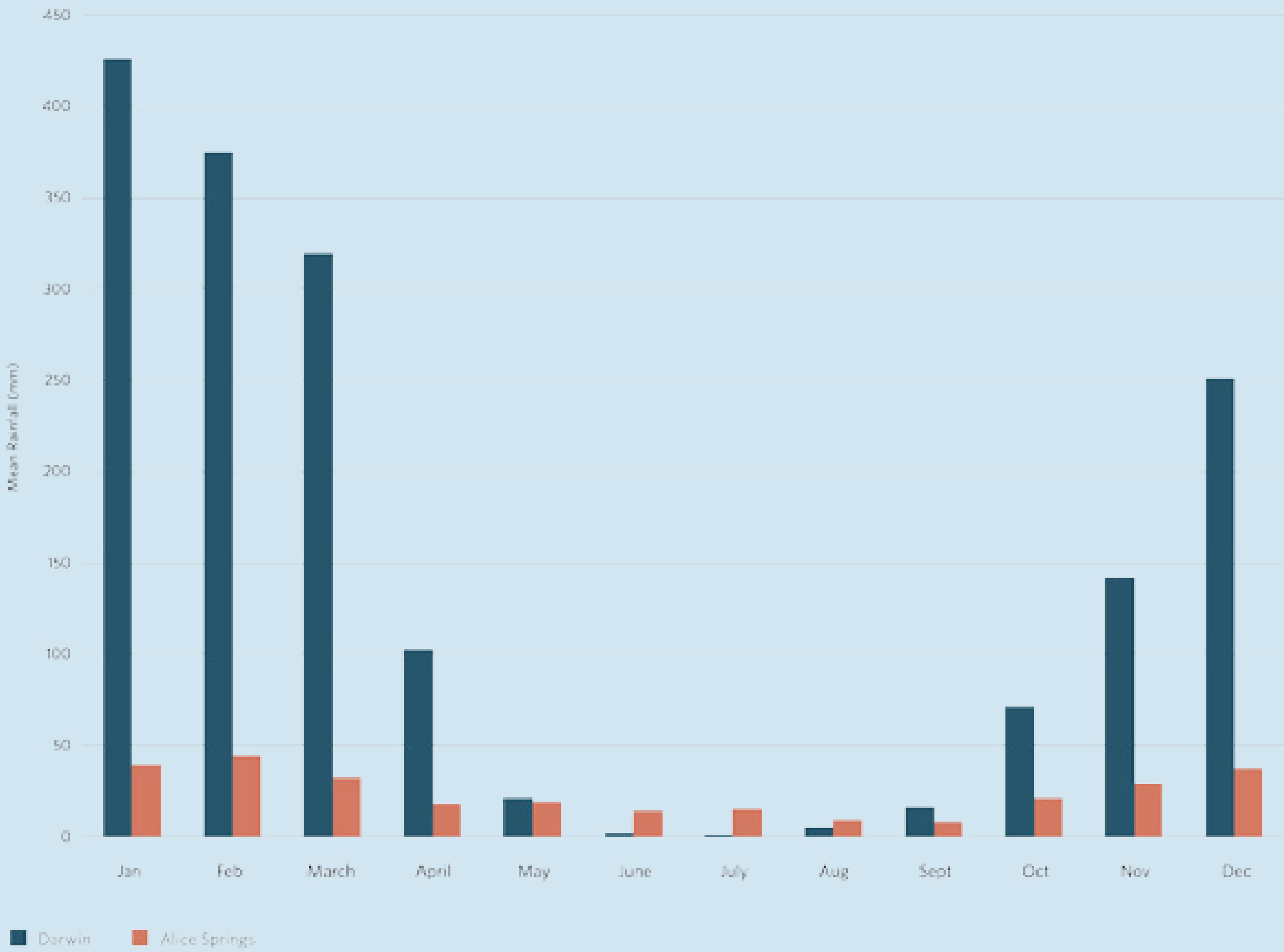
Recent research has suggested substantial historical variation in the intensity of the monsoon, including rapid change from about 6000 years ago, with periods of monsoon failure leading to prolonged aridity about 2400 to 1300 years ago, and consequential severe impact on the region's ecology and human population (McGowan *et al.* 2012).

In the summer, monsoonal rains flood rivers and wetlands of the north. The fertile floodplains, such as this one in Kakadu National Park, burst into life with prolific plant growth and breeding wildlife.

Figure 22

Mean Monthly Rainfall in Two Diverse Locations

A comparison between Alice Springs in central Australia and Darwin in monsoonal northern Australia



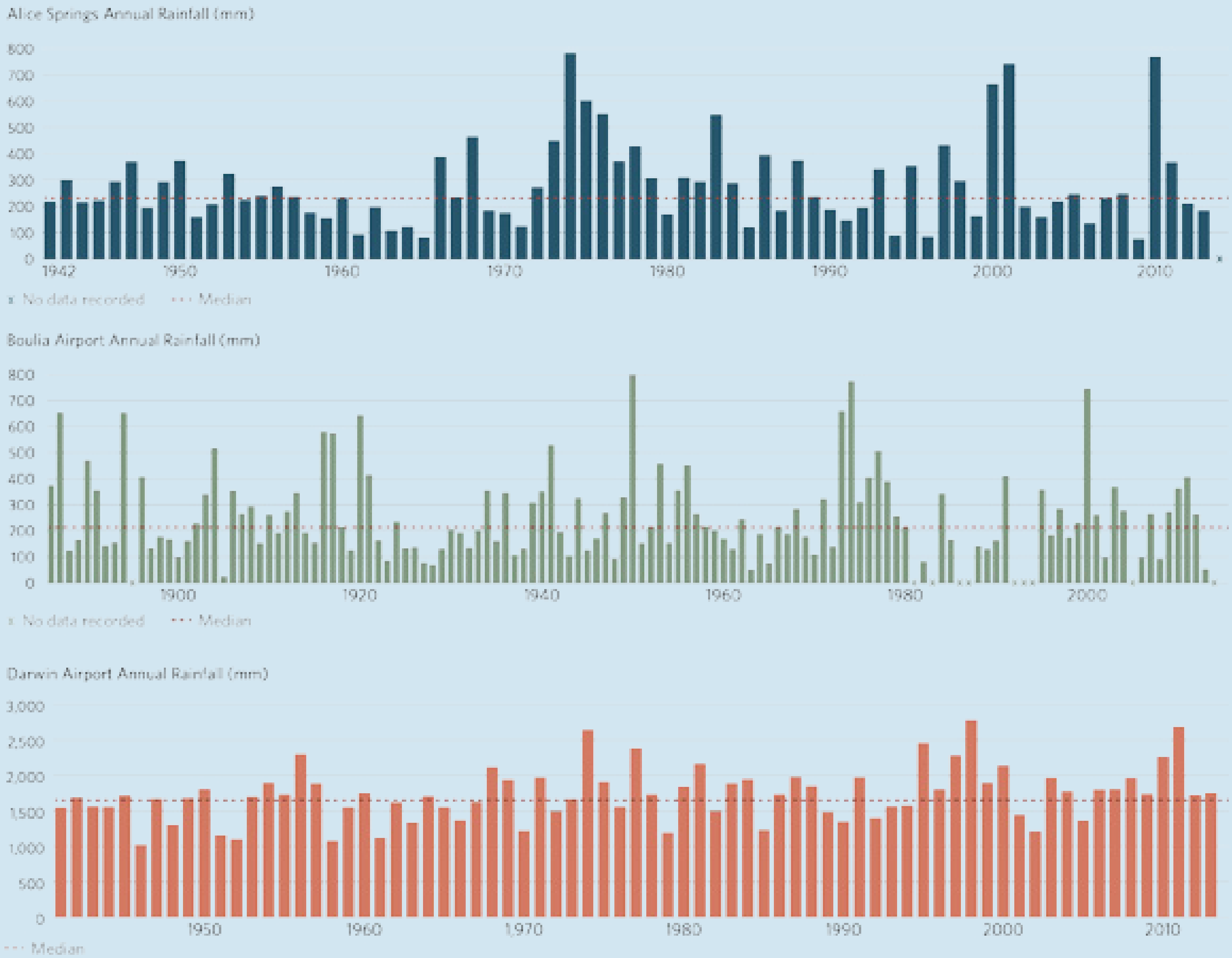
Source: Bureau of Meteorology

Figure design by The Pew Charitable Trusts

Figure 23

Variation in Annual Rainfall in 3 Diverse Sites

Alice Springs and Boulia in central Australia and Darwin in monsoonal north



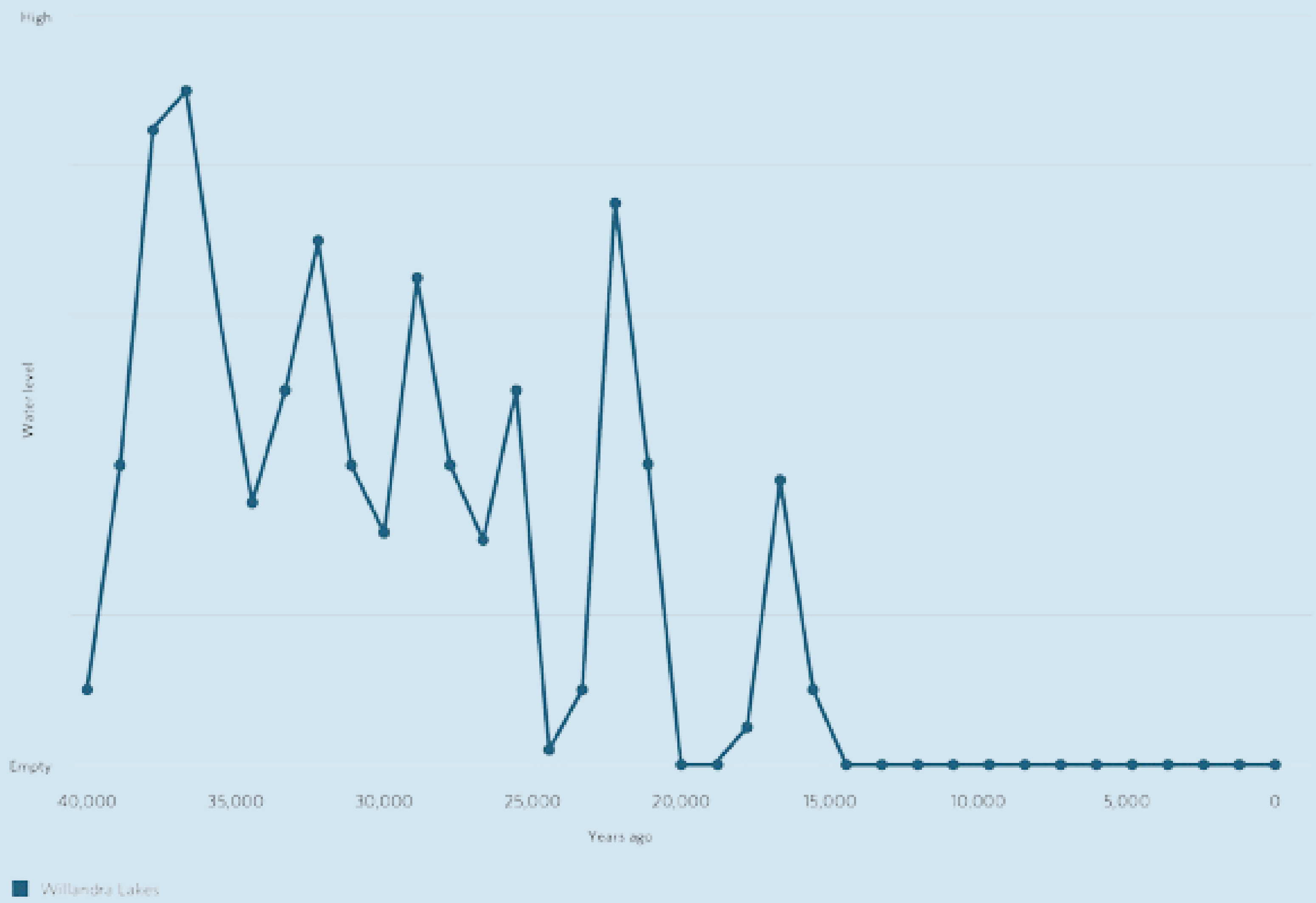
Source: Bureau of Meteorology

Figure design by The Pew Charitable Trusts

Figure 24

Historical Water Levels of Willandra Lakes System

Substantial changes in south-western New South Wales in past 40,000 years



Source: Modified from Smith et al. (2008)

Figure design by The Pew Charitable Trusts

The Bilby is one of Australia's most-recognised native animals, and also one of the most vulnerable. This burrowing marsupial is the last remaining of six bandicoot species that once lived in Australia's arid and semi-arid regions. Bilbies were common across most of the country but have disappeared from more than 80% of their former range.

5. The Outback setting: Nature, and how it works

The biodiversity and ecology of Outback Australia are distinctive and shaped largely by the physical and climatic factors described above, operating over a long history but influenced also by current land use and management. In this section we describe the ecological processes underpinning life in the Outback and sketch some of its biodiversity features.

> Fire, flood and drought – these are the calamities and caprice of nature in the Outback. They may bring destruction to human enterprises, but they are also natural forces that structure the ecology of the Outback and underpin much of its characteristics.

5.1. Knowledge about Outback nature

From a Western science perspective, the Outback includes some of the least-known lands in Australia. Access is constrained and expensive and there has been little sampling of biodiversity across large areas of the remote Outback – much remains to be discovered and documented (Figure 25).

Many Outback environments change markedly in time, so conclusions drawn from short-term environmental studies may be shown to be entirely awry when a longer perspective is taken. The significance and workings of some Outback ecological processes may take decades or more to discern and decipher (Morton *et al.* 2011; Dickman *et al.* 2014). To some degree, this also applies to spatial variation: the Outback may be vast and relatively homogeneous, but there is also substantial and important local nuance.

> Many of the most important insights into the ecology of Outback Australia derive from Indigenous knowledge.

Fortunately, over recent decades, there have been a number of notable long-term studies of Outback areas (Dickman *et al.* 2014) and perspectives from long-term resident Outback scientists (Morton *et al.* 2011), and such information has revealed much of the rhythm of Outback ecology over decades. Furthermore, recent collaborative studies have considered many disciplines of Outback ecology, allowing for more complex ecological questions to be viewed and interpreted from different perspectives (Stafford Smith and Morton 1990; Stafford Smith and McAllister 2008; Williams *et al.* 2009b; Morton *et al.* 2011).

But many of the most important insights into the ecology of Outback Australia derive from Indigenous knowledge:

' … their intellectual traditions – which are today's manifestation of the oldest intact human knowledge system in the world – tap the wellsprings of an understanding about landscape and life that has been built over tens of thousands of years. They have led researchers to a new way of understanding arid regions by looking below the surface, by observing patiently and reflecting, so that they begin to sense how things really work, how deserts function, how desert species adapt to extreme conditions, and how remote people find their way amid a landscape – physical, political, economic and social – that is constantly changing' (Ferguson 2012).

There are also other important knowledge sources:

'The pastoral and agricultural families also have their local knowledge, which is based on generations of experience of the diversity of rangeland conditions' (Ferguson 2012).

Increasingly, these diverse knowledge systems are being shared, respected and brought together to help understand the Outback and to deliver more informed management of its lands and environments.

5.2. Environments and species

Vegetation

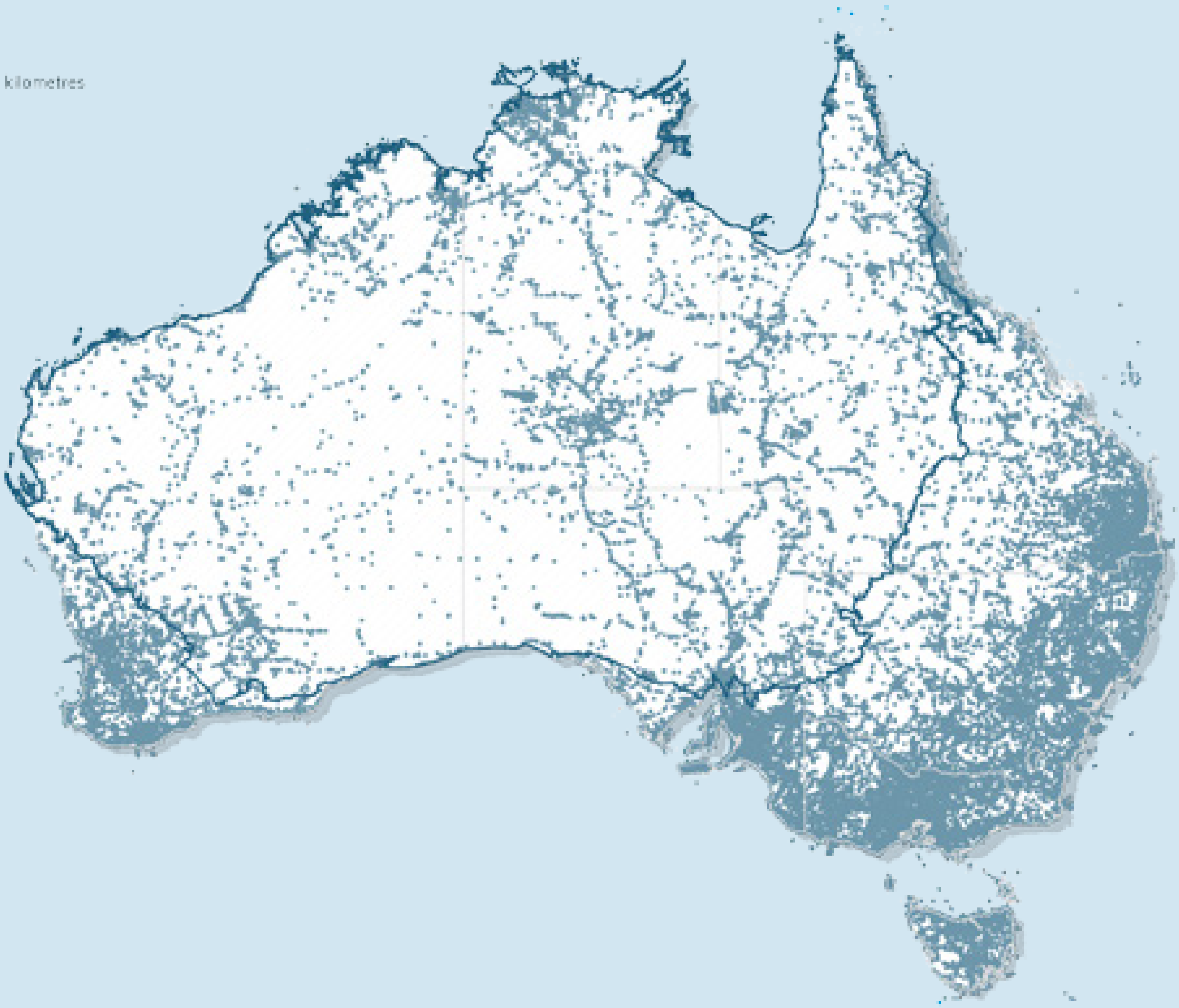
Outback vegetation types span a broad range from dense rainforests to almost plantless gibber (stony) deserts and saltpans. However, a small set of vegetation types dominates extensive areas and characterise the Outback (Figure 26). Tropical savannas and open eucalypt woodlands occupy most of monsoonal northern Australia, with the characteristic open forests dominated by Darwin Stringybark* and/or Darwin Woollybutt occurring across more than 400,000 km^2. These woodlands vary subtly in floristic composition and structure across that broad range, most notably with increasing stature in higher rainfall areas. As with savanna vegetation across the world, the understorey is dominated by a dense and tall grass layer, although a shrub layer may develop during longer periods without fire (Woinarski *et al.* 2004).

* Scientific names for plant and animal species referred to in the text are given in Appendix A.

Figure 25

A Mapping of All Australian Bird Records, Derived From the Atlas of Living Australia, Illustrating Sampling Bias Against Outback Areas

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: degree



Note: This map displays only a random 2% of all records

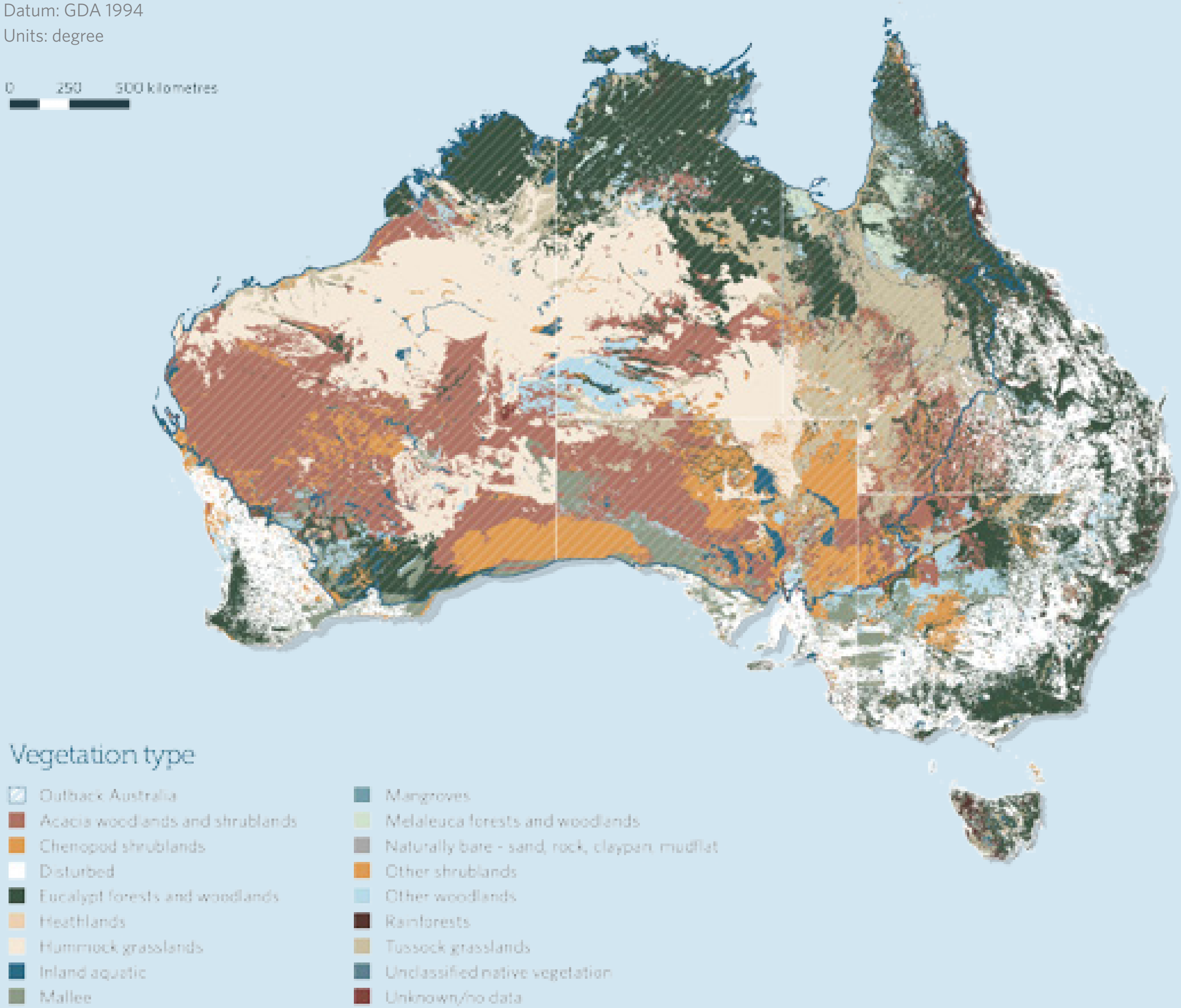
Source: Derived from the Atlas of Living Australia

Figure design by The Pew Charitable Trusts

Figure 26

Distribution of the Main Vegetation Types of the Outback

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: degree



Source: Based on data from the National Vegetation Information Service Version 4.1

Figure design by The Pew Charitable Trusts

Formations dominated by *Acacia* species (wattles) are another characteristic type of Outback vegetation and occur extensively across arid and semi-arid areas. These vary from woodlands dominated by a single *Acacia* species (most extensively Mulga, but also many other species including Gidgee, Weeping Myall and Lancewood) to floristically diverse low open shrublands. Low shrublands dominated by chenopods (mostly bluebush and saltbush species) occur in some heavier soils, most notably throughout the Nullarbor Plain and parts of northern South Australia. Across the vast sweep of arid and semi-arid Australia, hummock grasslands, dominated by a very diverse set of 'spinifex' species, are the major vegetation type and occur across a broad landscape range from deep sands in deserts to rugged rocky ranges with skeletal or no soils (see Spotlight 3). Tussock grasslands are more restricted but occur across some extensive areas of blacksoil plains at the southern fringe of the monsoonal tropics, in coastal floodplains of northern Australia and in alluvial floodout areas of the Channel Country and Lake Eyre Basin.

There are smaller areas of contrasting vegetation formations scattered across the Outback. These include mangrove forests and woodlands along much of the coastal fringe, particularly of northern Australia; mallee (multi-stemmed eucalypts) – low woodlands in the semi-arid fringe of the southern Outback; and diverse temperate eucalypt woodlands in semi-arid areas of south-western Australia (notably the Great Western Woodlands). There are also diverse heathlands in some coastal sandsheets and rocky ranges of northern Australia, scattered rainforests and gallery forests in fire-protected areas and permanently wet areas of northern Australia, and paperbark forests and woodlands in seasonally inundated and riparian areas predominantly in northern Australia. And there are narrow strips of woodlands often dominated by River Red Gum along riversides and lake margins across the Outback, and woodlands and shrublands dominated by native conifers (*Callitris* species) and by casuarinas (such as Desert Oak).

Boundaries between these vegetation types may be marked and abrupt or diffuse and gradational. Some of these boundaries are relatively fixed over long time periods, while others are more fluid and may vary over decades, typically in response to disturbance regimes. The extent and distribution of particular vegetation types has changed significantly over time, in response to variations in climate, but the main vegetation formations in the Outback have had a long history as important elements. The occurrence of vegetation types is influenced by many factors, but particularly by soil depth and texture, annual rainfall and its seasonality, minimum temperature, landscape position and fire regime. Some vegetation types are largely constant in plant species composition and structure over hundreds of kilometres, whereas others show remarkable fine-scale variation in floristics and stature. Many show substantial (successional) variation at any site in response to fire history.

The Outback's vegetation composition may also be characterised by counterpointing it with that of the rest of Australia. Most notably, the Outback is without the tall eucalypt ('wet sclerophyll') forests of eastern and south-western Australia, subtropical and temperate rainforests, alpine heathlands, grasslands and wetlands, and subalpine woodlands.

Tropical savannas are the main vegetation type across monsoonal northern Australia, with forests dominated by Darwin Stringybark and Darwin Woollybutt (pictured) extending over nearly half a million square kilometres. The typical structure of these woodlands comprises an open tree layer and a dense tall grass layer. Note that in this photograph, the grass layer has been consumed by recent fire.

A range of *Acacia* (wattle) communities dominates large areas of the arid and semi-arid Outback. The most extensive are woodlands and shrublands dominated by Mulga.

Spotlight 3 **Spinifex**

Eucalypts symbolise much that it is distinctive about Australian environments and *acacia*s (wattles) are equally diverse and ubiquitous. Both occur widely and are the dominant trees and shrubs across many Outback environments, and there are eucalypts – such as Ghost Gum, River Red Gum, Coolibah and Darwin Stringybark – and *acacia*s – such as Mulga, Lancewood and Gidgee – that are emblematic of particular Outback areas. But there is another defining vegetation component of the Outback: the Australian endemic grass genus *Triodia*, known generally (but with botanical imprecision) as spinifex, or in older vernacular as porcupine grass, or by ecologists as the definitive component of hummock grasslands.

Triodia occurs across the geographic sweep of the Outback and extends beyond it only in semi-arid fringes such as the mallee country of north-western Victoria. It occurs as the dominant ground layer in many Outback environments. It is the pivotal plant of deep sandy deserts in low rainfall areas but may also be the most abundant plant on sheer cliff faces or rock pavements in high-rainfall Outback areas. It is generally absent only on heavier (clay) soils dominated by tussock grasslands and chenopod shrublands, rainforests, aquatic environments, mangroves and coastal areas and some woodlands.

To the extent that plants have character, *Triodia* exemplifies the Outback. It is resilient and adaptable, harsh but sometimes beautiful, distinctively different from vegetation anywhere else, unwelcoming to the newcomer but the choice home for many Outback animals. It is often considered of little commercial utility – indeed some of the scientific names for *Triodia* species – such as *hostilis, irritans, inutilis, molesta, spicata, contorta and pungens* – are damning. While generally of little use for pastoralism, rain stimulates 'fresh pick' that cattle can graze and post-fire fresh growth is favoured by livestock (Lazarides 1997).

Triodia forms an Australian endemic 'tribe', *triodieae* (Jacobs 2004), in the grass family Poaceae 'without obvious relatives' (Lazarides 1997). They are long-lived perennial grasses characterised by a distinctive drought-adaptive leaf anatomy. They characteristically grow in a hummock formation and some species form rings due to 'the dying-out of the centre of the tussock with increasing age' (Lazarides 1997). The largest species form impenetrable clumps up to 2.4 metres high and six metres across. 'Characteristically, (they) survive all but the most severe, prolonged droughts by their anatomy for reducing transpiration from their leaves and by absorbing maximum moisture from soil particles by their ability to apply very high osmotic pressure. Also, (they) are deeply rooting, highly competitive, slow-growing and fire-surviving and the foliage of especially the resinous species is highly flammable even when green or damp' (Lazarides 1997). This is a group that fits into the Outback.

Triodia has had a somewhat messy taxonomic history. Many species are highly variable and the genus has sometimes been split, with a relatively small number of species variably placed in *Plectrachne* and *Symplectrodia*. In the first major revision of the genus, 28 species were recognised, including eight not previously described (Burbidge 1953). With the next taxonomic review in 1997, this tally had increased to 64 species, with 11 newly described species and absorption of the genus *Plectrachne* (Lazarides 1997). With ongoing review and the discovery of many narrowly restricted species (Barrett and Barrett 2011), the number of known species has increased to over 70. Some of these species are among the most abundant and widespread of Australian plant species, but others are among the more rare and localised. A notable example of the latter is the recent discovery of two new *Triodia* species from the small Ragged Range in the east Kimberley, including *Triodia barbata*, known from only about 300 individual plants growing on a 300-metre-long cliff edge (Barrett and Barrett 2011). This is a pattern that may be illustrative of the Outback more generally – much of the biodiversity richness is built up from fine-scale variations on broader-scale pattern.

Triodia also illustrates other features of the ecological dynamic of the Outback. For example, recent research has shown that some *Triodia* species (mostly 'soft' spinifexes) are associated with dune crests and other co-occurring species (typically 'hard' spiky spinifexes) are restricted mostly to the swales (the valleys between dunes), reflecting different capabilities under the varying nutrient and water characteristics of these abutting environments. More persistent water availability in the dunes (because of deeper soils and associated increased water storage capacity) allows for the penetration into drier environments of dune-associated species more typically associated with higher-rainfall areas (Grigg *et al.* 2008).

In some Outback locations many different *Triodia* species may co-occur. For example, more than 12 *Triodia* species have been reported in Purnululu National Park (the Bungle Bungle Ranges) (Woinarski 1992), and this richness was noted as one of the factors contributing to the World Heritage status of the park area (Environment Australia 2002). Across much of the Outback, the ability of many *Triodia* species to co-occur is due to subtle environmental factors determining co-existence and the niches occupied by different species (Armstrong and Garnett 2011). *Triodia*

The grass genus *Triodia*, generally known as spinifex, is a characteristic component of the hummock grasslands found widely throughout the Outback. The richness of *Triodia* species in Purnululu National Park in far north Western Australia, such as this example, contributed to the area's listing as a World Heritage area (top left). Spinifex is characteristic of many vegetation types from the deserts to the rocky ranges of the Kimberley and Top End. This example is on a hillside in Palm Valley, West MacDonnell Ranges, in the Northern Territory (top right). Many spinifex species form a characteristic ring-shaped pattern as they age, such as these clumps in the Little Sandy Desert, Western Australia (above).

may also be relatively fire-tolerant – indeed it may promote fire. Many Outback areas may have an unstable boundary between *Triodia*-dominated hummock grasslands and more fire-sensitive vegetation types such as Mulga woodlands. With frequent and high-intensity fire, the extent of *Triodia* vegetation may increase at the expense of the more fire-sensitive vegetation types, especially on less fertile sites (Murphy *et al.* 2010).

But these ecological interactions may vary across the Outback. A recent overview concluded:

'… the spinifex ecosystems of the western half of the desert are rejuvenated by fire, and those in the eastern half of the desert are rejuvenated by water (in the form of extensive floods)' (Smith 2013).

Spinifex provides an interesting example of how Outback ecosystems function, but it also plays a pivotal role in Aboriginal culture and as habitat for many animal species. Many *Triodia* species – especially 'soft' spinifexes – produce a viscous resin (gum) and this resin is essential in tool-making:

'An extremely important component of Aboriginal technology is the cementing substance obtained from soft spinifex (Triodia spp.) and it is hard to imagine survival in the desert environment without it. This resinous material is vital for the construction of tulas (the basic woodworking tool) but it is also used in the construction of many other implements or to repair broken ones. The cementing substance obtained from Triodia species may well be the strongest and most malleable of any in Australia.

Spinifex is the ideal habitat for many lizard species, providing protection from predators and a ready supply of insects to feed on. The Jewelled Gecko, pictured, spends its entire life among clumps of spinifex.

… Even in those areas where the resinous spinifexes are common, people in the past would have travelled as far as 80 km into what was usually inhospitable country to find it' (Latz 1995).

Spinifex also had many other uses, including as material in art, for construction of shelters and fish nets (Latz 1995; Gamage *et al.* 2012).

'Hard' spinifexes are colloquially known as porcupine grasses because of their dense array of very hard spiny foliage: 'it is almost impossible to put your hand into the tussock'. So-called 'soft' spinifexes are only a little gentler: 'one can, with care, put one's hand into the tussock' (Latz 1995). Wherever spinifexes occur in the Outback, this armour provides an important shelter for an extraordinarily large number of animals. *Triodia* occurrence is the key factor in defining habitat for many endemic Outback animals, notably including many grass-wrens, emu-wrens, the Night Parrot, some finches, many geckoes, pygopodids (legless lizards), skinks, some snakes, hopping-mice, dunnarts and ningauis (small carnivorous marsupials), bandicoots and small wallabies.

One example has been recently described in detail (Churchill 2001). The Sandhill Dunnart typically nests in large spinifex hummocks that have started to die off in the centre. They enter these hummocks by leaping up onto them and climbing over the needles to the centre before scrambling down through the central portion of dead leaves. In the centre of the hummock they built a circular depression within the dead spinifex needles, or occasionally dig burrows, starting from inside the spinifex with the burrows spiralling down under the plant. Such intimate use of spinifex provides protection from predators for much of the lifetime of these animals.

Another example is the set of tiny jewelled geckoes, *Strophurus* (*Diplodactylus*) species, that spend their whole lives in and around spinifex clumps (Pianka and Pianka 1976; Robinson *et al*. 2003). In one study, the gecko *Diplodactylus elderi* was found to be 'intimately associated with and dependent upon spinifex. … [they] were almost always found inside such grass clumps, except for a few which were invariably immediately adjacent to a tussock. … its prehensile tail and climbing abilities suggest that [it] must frequently climb within *Triodia* tussocks' (Pianka and Pianka 1976). Indeed, spinifex itself is considered to be 'an important factor contributing to lizard diversity in Australia. … spinifex tussocks are extremely well suited for lizard inhabitants, providing as they do not only protection from predators and the elements but also a rich insect food supply. … Certain lizard species … appear to spend almost all their time within dense *Triodia* tussocks. Others … tend to occur around the edge of spinifex tussocks. Still other species … frequent the more open spaces between tussocks' (Pianka 1981).

In many cases, the association of animal species also depends on *Triodia* size and age, with the much larger size of longer-unburnt *Triodia* hummocks being essential for habitat suitability (Masters 1996; Nimmo *et al.* 2013).

Much of the value of spinifex to wildlife is determined by the refuge that it provides against predators, but it provides other resources – for example, *Triodia* species are the only host plants for some butterflies (Atkins 1973) and its seeds may be pivotal for the survival of some bird and rodent species.

Spinifex may underpin much of the ecological functioning and character of the Outback (Morton and James 1988). It can develop relatively high biomass but its foliage is largely unpalatable to most vertebrate herbivores and is relatively nutrient-poor. The relative availability of nutrient-poor but cellulose-rich spinifex foliage favours consumption by termites, leading to an unusually high abundance and diversity of termites in spinifex grasslands and a consequently high diversity and abundance of the many species of vertebrates that feed on termites (Morton and James 1988). The availability of substantial biomass in the ground layer in arid environments also predisposes those environments to frequent fire, which reshapes the desert landscape. Spinifex grasslands notably vary in structure and plant species composition with time since fire, and associations of different vertebrate species with these varying successional states is one of the main factors that allows many species to co-occur in spinifex landscapes (Pianka 1989, 1996).

Wetland systems

For such a predominantly dry land, there is a surprisingly high diversity of wetland environments across the Outback, with markedly different patterning and composition in monsoonal areas compared with arid and semi-arid areas. In central Australia, isolated springs, soaks and waterholes in rugged sheltered gorges may provide the only near-permanent natural water sources, and these have been instrumental for supporting the persistence of many species, including humans, in these environments over long periods. One such example is Palm Valley in the Western MacDonnell Ranges, which now supports a range of relict species (Wischusen *et al.* 2004), although the most celebrated of these presumed remnant species – the palm species that gives its name to the location – is now recognised to not be a relict but more likely to be due instead to translocation by Aboriginal people sometime in the past 20,000 years (Kondo *et al.* 2012; Trudgen *et al.* 2012). In many desert areas, some waterholes were modified and protected by Aboriginal societies to increase water security.

Ghosts of rivers past – the legacy of periods of wetter climate – still wind through desert country in the form of palaeochannels. These sinuous sandy landscape features may still provide important habitat for some plant and animal species.

Other desert river channels fill and flood after large rainfall events. At such times some of these rivers may have very substantial flows. Some of these dryland rivers – such as the Murchison, Gascoyne and Fortescue river systems in Western Australia – flow directly to the sea within the Outback region. Others, such as the Diamantina River and Cooper Creek systems, end in inland lake systems. Still others, such as the Finke River, peter out in deserts. Some of these systems dry completely, but others maintain some waterholes and billabongs through most dry times, and these near-permanent bodies of water may be crucial for the persistence of many species (Fensham *et al*. 2011; Kereszsy *et al.* 2011), and for cultural and social reasons. Some inland watercourses have narrow and well-defined channels, but others – especially in areas with little topographic variation – may become a diffuse maze of parallel and interconnecting braided channels.

Inland Australia includes a surprising number and range of lakes and swamp systems, most of which are non-perennial and experience marked differences from year to year in size, shape and productivity. Some lake systems – notably Lake Eyre and nearby lakes – are shallow and saline, while others – including Lake Woods and Gregory, and the lake systems of the Barkly Tablelands – are fresh. Many of these inland lakes and swamps provide breeding sites for large numbers of highly dispersive waterfowl, fish and other aquatic animal species. So, the pelicans loitering off a pier in Adelaide or Brisbane may well have been born in a wetland of the remote inland.

In climatically erratic but largely dry inland Australia, artesian basins – most notably the Great Artesian Basin – provide a notable contrast, with relatively stable underground water resources. In some areas, the artesian basin lips the ground surface at mound springs and these discharge areas have long provided small and widely scattered lenses of reliable water (Fensham *et al.* 2011).

Other aquifers, sinkholes and subterranean water sources across the arid and semi-arid Outback provide habitat for a mostly poorly known assemblage of narrowly endemic stygofauna (underground invertebrates and fish).

There are no large artificial lakes in arid and semi-arid Outback Australia, but there is an increasingly large network of smaller artificial water points, mostly established as drinking sites for livestock. They have substantially increased access for stock to lands that were formerly not subjected to grazing pressure.

Unsurprisingly, wetland systems in monsoonal northern Australia are notably different from those in more arid Outback areas. Fifty-five major drainages are distributed across northern Australia, with a total river length of 761,000 kilometres. Collectively they discharge about 180,000 gigalitres of water per year, 46% of the total Australian run-off (Kennard 2010).

All river systems in northern Australia have marked seasonal variation in flow. But there are some large perennial rivers – such as the Daly River – for which groundwater inputs through a set of springs and aquifers provide reliable year-round water flow.

Many permanent rivers support gallery forest and different, richer and more specialised aquatic communities to those of rivers that dry or cease flowing in the rainless periods. Many of these river systems span a wide spectrum of habitats across their extent, from headwaters comprising springs and soaks of the rugged uplands (the 'Stone Country'), through spectacular waterfalls and plunge pools at escarpments in the upper catchment, gallery forests along extensive mid reaches, a complex mosaic of billabongs, swamps and floodplain areas in the lower catchment, to end in extensive tidal reaches (for example, with tidal influences extending more than 100 kilometres upriver in the South Alligator River) and productive mangrove and estuarine systems.

Recent mapping has indicated that there are about 8000 individual lacustrine features (large water bodies in depressions or river channels that are largely open water) in northern Australia, covering a combined area of about 1000 km^2 (Kennard 2010). There are about 18,000 palustrine

Grazier-riverkeeper, Angus Emmott, from Noonbah Station in western Queensland's Channel Country. Angus, pictured rowing on Broadwater Channel, part of the Thomson River system, is one of many landowners in the region fighting to keep the rivers flowing to Lake Eyre.

features (floodplains and vegetated wetlands) in monsoonal northern Australia. These include large seasonally inundated floodplains, especially in the Gulf of Carpentaria region, where floodplains may cover more than 20,000 km^2. This includes Australia's largest wetland, which occurs in peak flood years, the drably named 'Southern Gulf Aggregation', formed when massive floods link adjoining river floodplains. Given that rainfall is greatest near the coast, a substantial proportion of the total run-off from many northern rivers may originate from lowland regions. As a consequence, floodplain wetland habitats of northern Australia are vast (Kennard 2010). There are also some large tree-covered permanent wetlands, most notably including the palm and *Melaleuca* wetlands of the Arafura Swamp in central Arnhem Land.

Species

Many of the characteristics of plant and animal species in the Outback are features of Australian biodiversity generally. A significantly high proportion of plant and animal species are endemic to Australia and many of these groups have a longstanding evolutionary history on the continent, or as part of its former connection within Gondwanaland. Diversity is very high for some plant and animal types, including reptiles, some invertebrate groups (particularly ants) and some plant groups. The biomass of some groups, such as ants and termites, may be exceptionally high.

However, there are also notable contrasts between the biodiversity of the Outback and that of other parts of Australia. Some of the iconic Australian species, such as the Koala, Platypus and lyrebirds are absent from (or occur only marginally in) Outback areas. But the Outback is also the main or only home for other iconic species, including the Emu, Frilled Lizard, Bilby, Perentie, Gouldian Finch, Budgerigar, Night Parrot, Red Kangaroo, Mulga and Boab. Among vertebrate species, there is marked phylogenetic distinctiveness (i.e. they are markedly unrelated to any other species) in some Outback groups including the marsupial moles (two *Notoryctes* species in their own order, the Notoryctemorphia, which may have branched off from other lineages as much as 64 million years ago: Kirsch *et al.* 1997). Other highly distinctive groups include the bilbies (one extant and one extinct species making up the family Thylacomyidae), the now-extinct Pig-footed Bandicoot (the sole modern species in the family Chaeropodidae) and the relict Banded Hare-wallaby (the sole modern species in the subfamily Lagostrophinae).

Many plant and animal species occur extensively across the Outback, but others have very narrow ranges and are highly habitat-specific. Some habitat types and regions have particularly high richness or concentrations of restricted-range species. For plants, there are important centres of endemism in south-western Australia (partially overlapping the Outback area), the Kimberley, the western Arnhem Land plateau and Cape York Peninsula (particularly the Iron and McIlwraith ranges), with regionally important endemic-rich areas in the central ranges (Crisp *et al.* 2001). Many of these areas support plant species that are biogeographic oddities, of unusually ancient lineage or phylogenetically distinctive.

The Kimberley has about 2000 plant species, of which about 300 occur only there; Cape York Peninsula has 3000, including at least 260 unique species; and western Arnhem Land has at least 200 endemic plants (Woinarski *et al.* 2006).The Great Western Woodlands has more than 3000 plant species. It is particularly rich in eucalypts with about 30% of Australia's eucalypts occurring in an area that is less than 2% of the continent's extent.

The Outback's centres of endemism for plants also tend to be important for many other groups. For example, there are many restricted-range invertebrate, fish, mammal, reptile, frog and bird species in the Kimberley, western Arnhem Land and Cape York Peninsula. However, the patterns also show some significant variation among groups. Some areas have high endemism for some groups but a different set of areas will be more important for other taxonomic groups of species (Figures 27, 28). Given such spatial variation in sites of endemism, the breadth of Outback biodiversity cannot be readily encompassed within a nominal system of conservation reserves.

The plant and animal assemblages of arid Australia are highly distinctive and there is a generally high rate of endemism. Most arid-zone species' lineages date to the Pliocene (5.3–2.6 million years ago) or earlier (Byrne *et al.* 2008).

The Outback is particularly important for some species groups. It is home to one of the world's most diverse reptile populations. (Pianka 1969; Pianka and Goodyear 2012), with high richness at any site and also substantial turnover in reptile species composition between habitats and sites. Major hot spots for lizard diversity run from central Australia west to the Hamersley Range and Pilbara coast and north to the Kimberley (Powney *et al.* 2010). The sphenomorphine skinks – notably including the particularly species-rich genus *Ctenotus* – are among the most diverse groups in the Outback, with most of the 232 known Australian species occurring in the interior drylands diversifying 'explosively' as Australia dried out over the past 20 million years (Rabosky *et al.* 2007).

This is just one of the dozens of billabongs and wetlands flanking the Archer River on Piccaninny Plains Wildlife Sanctuary, Cape York Peninsula, north-eastern Australia. The 170,000-hectare sanctuary, managed by the Australian Wildlife Conservancy, has a rich diversity of plants and wildlife spread across rainforests, woodlands, wetlands and grasslands.

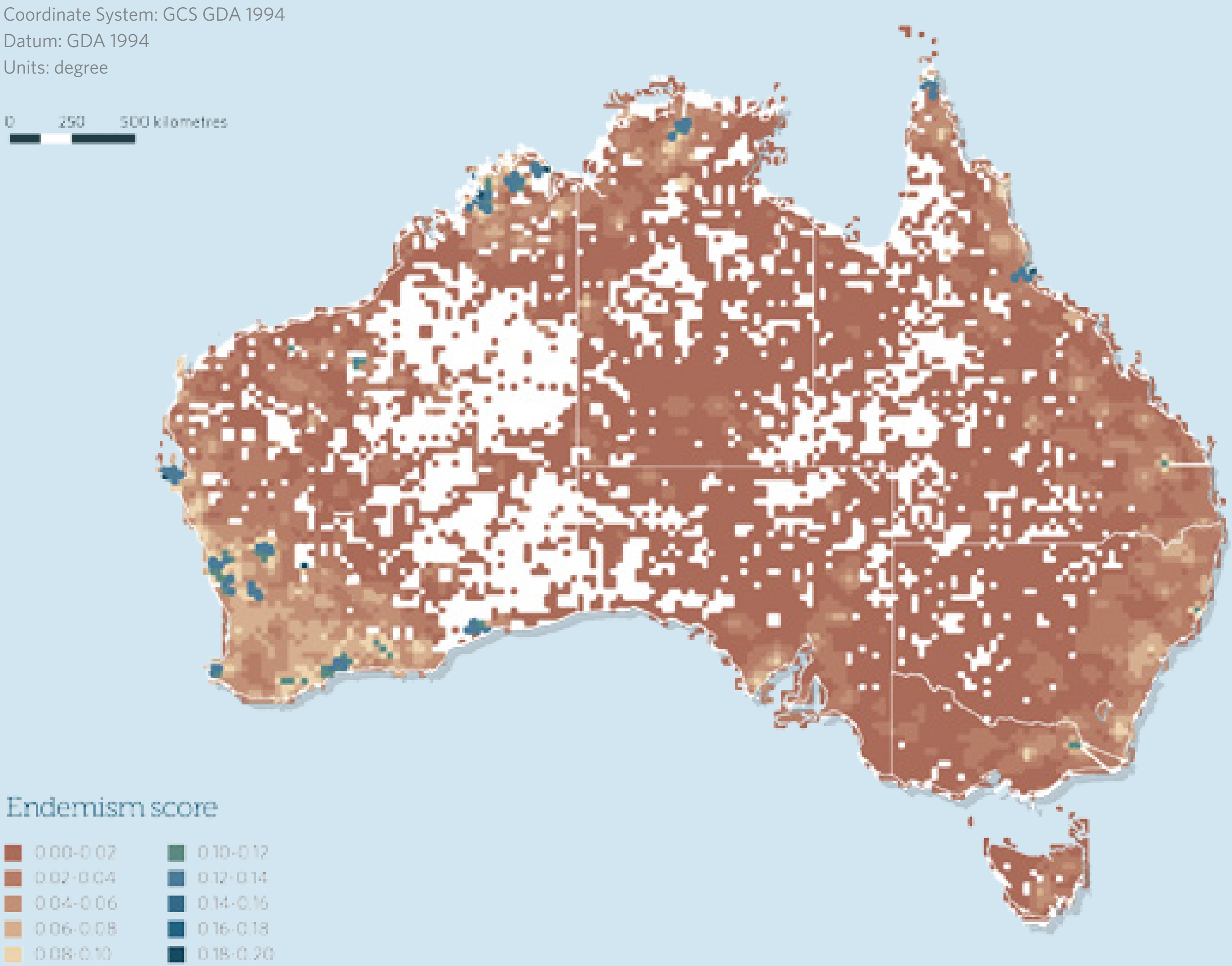
Emus, such as these at Coongie in north-eastern South Australia, are found throughout the Outback. They have declined in the northern savannas in recent decades because of altered habitats from changed patterns of fire and, in some cases, grazing.

The male Red Kangaroo is the largest native animal in the Outback and the world's largest marsupial, growing up to 1.4 metres tall. It is well adapted to hot dry conditions where rainfall is less than 500mm per year.

Many desert birds, such as Budgerigars, cover large distances tracking erratic rainfall events, which provide the pulses of food and water they need to survive and breed.

Figure 27

Patterns of endemism in Australian *Acacia* species



Source: From González-Orozco CE, Laffan SW, Miller JT (2011) Spatial distribution of species richness and endemism of the genus *Acacia* in Australia. *Australian Journal of Botany* 59, 601- 609. (http://www.publish.csiro.au/nid/65/paper/BT11112.htm).

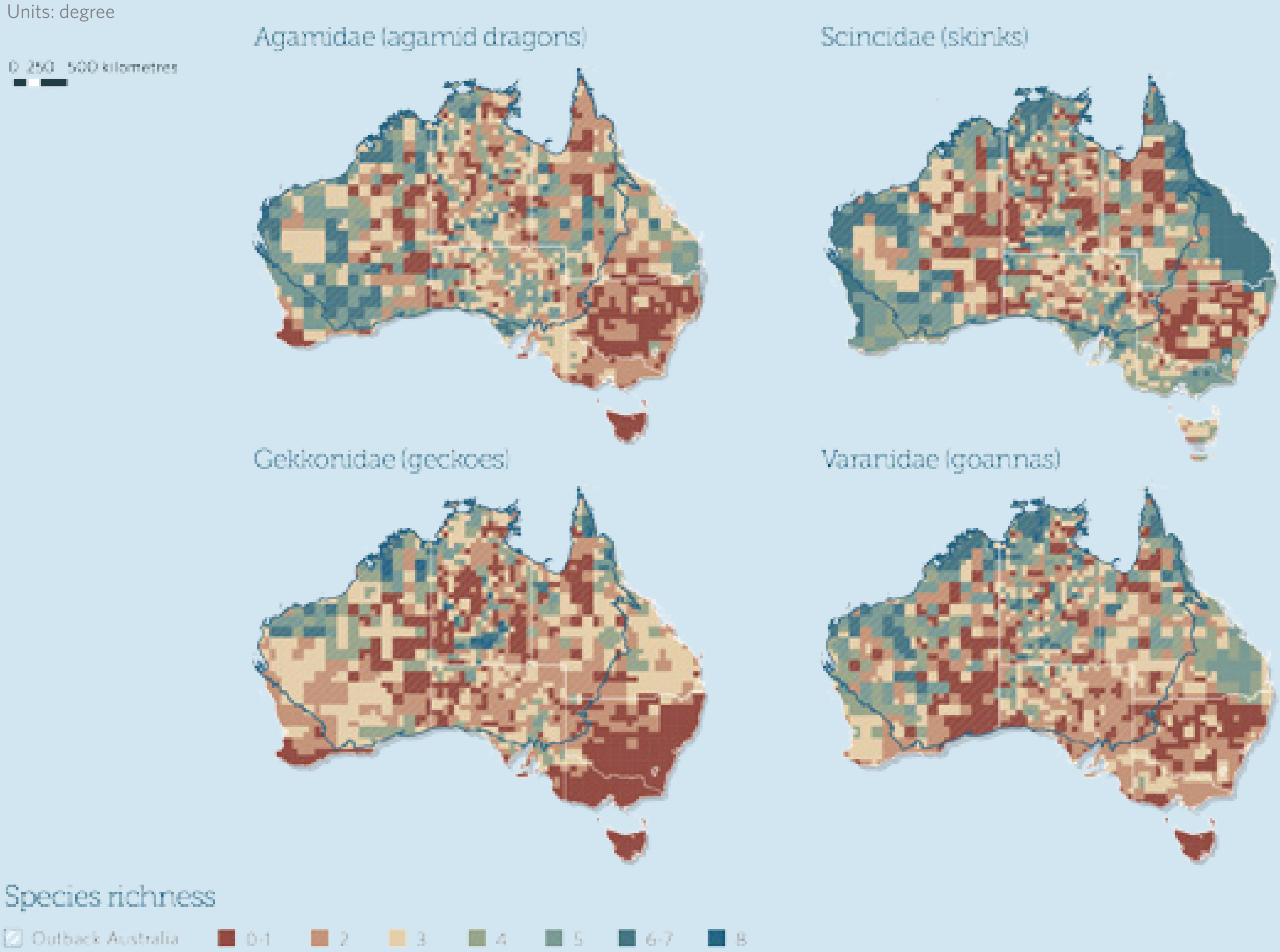
Figure design by The Pew Charitable Trusts

Figure 28

Number of Lizard Species in Four Families Occurring in 1° Cells in Mainland Australia

Geographic Patterns of Richness Demonstrated Across the Outback

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: degree



Source: Based on data from Australian Natural Heritage Assessment Tool, which includes species' location records from Australian museums, Australian herbaria, Birds Australia, CSIRO, state and territory governments and other sources

Figure design by The Pew Charitable Trusts

The Outback is home to a particularly rich diversity of lizards, with the sphenomorphine skinks, such as this representative from the *Ctenotus* genus, among the most diverse groups. There are more than 230 known species of skink in Australia's dry interior.

Outback ant communities are also among the richest in the world, with typically high diversity in any area. For example, surveys in one-hectare areas have inventoried 100 or more species (Andersen 1992, 2000). There is also a substantial turnover in species composition between nearby habitats and between regions. Australia's dryland ant communities are the most diverse in deserts worldwide, with two to three times as many species as in comparable habitats elsewhere in the world (Andersen 2003). There are at least 1500 known ant species from northern Australia, but many more are likely to be discovered (Andersen 2000). A recent survey of the Mitchell Falls area in the Kimberley found that about a third of the 166 species collected are known only from that area and about half are restricted to the Kimberley (Andersen *et al.* 2010). Numerous new ant species are regularly discovered not only in previously unsampled regions, but also in some habitats in relatively well-sampled areas: for example, new survey procedures are now uncovering a hitherto unexpected high diversity, and unusual assemblage, of subterranean ants in northern Australia (Andersen and Brault 2010).

The exceptional richness of ants in the Australian Outback is driven in part by the availability of carbohydrates from sweet exudates – mostly excreted by insects that live by sucking up liquids in plant foliage and stems – and nectaries (glands) especially on *Acacia* species (Andersen 2003). Ants are ecologically influential, regulating the abundance of other insects, dispersing seeds, and aerating and turning the soil. Seeds from about 1500 Australian plant species are dispersed primarily by ants.

Termites are numerous and ecologically important across most of the Outback. The number of termite species is highest in Cape York Peninsula, the Top End, central Australia, the Pilbara and the southwest (Woodman *et al*. 2008). Termite abundance is highest in tropical savannas, where colonies with up to four million individuals build spectacular mounds as high as seven metres. More than 100 species have been recorded from northern Australia (Watson and Abbey 1993; Bowman *et al.* 2010a). In central Australia, termites are the principal consumers of live and dead plant material and may reach very high biomass. For example, in a paddock grazed by cattle in central Australia, the estimated biomass of a single termite species (20–25 kg per hectare) was about double that of the cattle (Watson *et al*. 1973). Termites are major players in soil processes – facilitating decomposition; regulating nutrient and energy flows; promoting soil formation, turnover and porosity; and influencing the distribution of plants and micro-organisms (Dawes-Gromadzki 2005).

More than 100 termite species have been recorded in northern Australia, including a high diversity on Cape York Peninsula. Conical termite mounds dot the tropical savanna in Cape York's Mungkan Kandju National Park (left); black mounds stipple the Peninsula's Normanby floodplain (right).

A highly diverse radiation of land snails is another biodiversity feature across many Outback areas. Hundreds of species have been described from the Kimberley, many narrowly restricted to single rainforest patches (Solem 1991; Solem and McKenzie 1991) or islands (Gibson and Köhler 2012), and such high diversity and narrow endemism of snails is also a feature of some limestone environments in monsoonal areas of the Northern Territory (Braby *et al.* 2011). It is perhaps surprising that there is also a high diversity and pattern of narrow endemism of land snails in parts of arid central Australia (Slatyer *et al.* 2007a). Many of these species are restricted to very small patches of denser vegetation in areas of rugged topography that are sheltered from fire.

Outback aquatic communities may also be diverse and show some narrow endemism. This is particularly the case for upland streams of higher rainfall areas of monsoonal northern Australia (Bruce 1993; Short *et al.* 2013) and there is also substantial variation among catchments in the composition of aquatic communities. Rivers and other wetlands in the northern Outback support most of Australia's freshwater reptile species (crocodiles, turtles and aquatic goannas), fish species and the majority of species for many aquatic invertebrate groups. For example, there are more fish species in some Kakadu waterholes than in the entire Murray–Darling system (Woinarski *et al.* 2007). Many wetland bird species are also abundant in these environments: for example, the iconic and phylogenetically unusual Magpie Goose congregates in flocks of tens of thousands at remnant waterholes at the end of the dry season.

Not unexpectedly, there is generally less aquatic biodiversity in arid and semi-arid Outback areas. However, there are important assemblages of some aquatic groups and particular sites in the arid and semi-arid Outback contain unusual, diverse and restricted range aquatic species. Wetland systems in the Lake Eyre Basin support 27 fish species, of which 13 occur nowhere else. While most sites of high frog diversity and endemism are in high-rainfall areas – including the Kimberley and Kakadu area – there is also surprising diversity in some inland low rainfall areas: for example 15–20 frog species have been reported from the semi-arid Paroo River system (Slatyer *et al.* 2007b).

Artesian springs that discharge on the western side of the Great Artesian Basin often contain distinctive assemblages of plants, fish, snails and other invertebrates and many species occur only at one or a few springs (Fensham *et al.* 2010).

These land snails reflect the high diversity of snails found in many Outback areas. The examples pictured, all in the Camaenidae family, are from Western Australia's Kimberley region.

By the end of the dry season, tens of thousands of magpie geese can be found at remnant waterholes.

In many Outback areas, there are complex underground environments harbouring unusual animal assemblages often characterised by species with narrow endemism and probably very ancient origins. Because of widespread aridity and a limited area of limestone karst habitats, Australia was considered 'a poor prospect for subterranean fauna'. Now, it is recognised as a global hot spot, with probably more than 4000 species of these stygofauna in the western Outback alone, of which an estimated 80% remain undiscovered (Guzik *et al.* 2010). Limestone deposits in many Outback areas – particularly in western Australia – are riddled with holes and crevices filled with water, and in this water are crustaceans, beetles, fish and other animals. One bore in the Pilbara yielded 32 species (Eberhard *et al.* 2009). The Outback has the world's greatest diversity of subterranean diving beetles, and individual aquifers have up to five unique species (Leys *et al.* 2003). There is also a diverse array of blind crustaceans such as amphipods and isopods (Cooper *et al*. 2007; Cooper *et al*. 2008).

There are many islands off the Outback coast, often with substantial conservation values due to the occurrence of endemic species and the absence of some threatening factors that have caused broad-scale declines in mainland populations. Many are also important as seabird rookeries, nesting sites for marine turtles and as feeding sites and staging posts for migratory shorebirds. This set of islands includes Australia's second (after Tasmania) and its fourth- and fifth-largest islands: Melville (5786 km^2), Groote Eylandt (2285 km^2), and Bathurst (1693 km^2), respectively. It also includes many individual islands, such as Barrow Island, and island groups such as the Sir Edward Pellew islands, the Wessel islands, and sets of Kimberley islands, that are critical for the conservation management of many threatened species.

5.3. Ecological processes

Fire, flood and drought – these are the calamities and caprice of nature in the Outback. They may bring destruction to human enterprises, but they are also natural forces that structure the ecology of the Australian Outback and underpin much of its characteristics.

Deciphering – or at least being aware of – the bewildering complexity of nature in the Outback is vital to understanding how to maintain its viability, resilience and beauty. Nature is far more than a collection of species and habitats. These are important, just as individual people are. But in the same way that it is the network of interactions, relationships, rules and morals that gives place and context to individuals within communities and renders a society far more than simply the sum of its individuals, so also in nature: it is a network of interactions, processes and natural laws that connects individual species and environments and crafts functioning ecosystems. So

Insight 4

What are the important ecological processes in the Outback?

People readily see nature as a collection of individual plant and animal species, and of coherent sets of such species in the form of habitats or environments. But these are the simple and overt physical manifestations of a far more complex system, which is bound together and defined by a series of ecological processes (or functions). These are mechanisms that govern the interrelationships among species, between an environment and its location, and of the variation in biota over time and space.

A recent review identified a tapestry of ecological processes and connections that underpin Australian environments (Soulé *et al.* 2004), concluding that these are what make Outback environments work:

- hydro-ecology: the links between water, vegetation and wildlife, including water flows below and above the ground;
- disturbances, including fire, storms and cyclones, and flooding;
- long-distance biological movement, such as animal migration and seed dispersal;
- strong interspecies interactions, such as the role of top predators in structuring food webs and the population dynamics of their prey species, and hence of the plants and other resources on which, in turn, they depend;
- climatic change and variability, both natural and human-induced;
- land and sea connections, resulting in the exchange of water, biota and nutrients between land and sea; and
- evolutionary processes at all scales, such as the patterning of genetic variation and its dynamism across land and seascapes.

Each of these processes operates over many scales and time periods, with or without regularity. Understanding the workings of these processes is a key to understanding the Outback. Ensuring the maintenance and functionality of these processes will be necessary to sustain the Outback's biodiversity and Australians' life within it.

nature includes, and is driven by, movements of energy, water and nutrients between non-living and living elements at multiple scales. It is destruction and renewal driven by fires, flood and storms. It is movements of animals seeking food and mates, and the interactions between species – predation, competition, cooperation and symbiosis. Underpinning nature is a network of ecological processes, 'the natural machinery that connects living and non-living things and keeps nature healthy' (Traill 2009).

> Deciphering – or at least being aware of – the bewildering complexity of nature in the Outback is vital to understanding how to maintain its viability, resilience and beauty.

There are many ecological processes operating across varying scales of time and space. One review (Soulé *et al.* 2004) identified seven ecological processes and connections operating at a continental scale in Australia that are key to understanding its environments and their management (Insight 4). These are all relevant for understanding the ecology of Outback Australia. More specifically, the arid zone ecologists Steve Morton and Mark Stafford Smith have recently described the important ecological traits and drivers of arid Australia (Insight 5). They also identified process 'weak points' – parts of the mechanism that may be particularly sensitive and that, if pressured, may cause the collapse or degradation of the process more broadly (Stafford Smith and McAllister 2008). The identification and wise management of such weak points may be pivotal for ensuring the sustainability of land use.

Insight 5

A framework for the ecology of arid Australia

In 1990, ecologists Mark Stafford Smith and Steve Morton, from CSIRO, provided a framework for understanding the ecology of arid Australia. They considered that the pivotal climatic and physical features were rainfall variability – leading to extended droughts and occasional flooding rains – and widespread nutrient poverty interspersed with much smaller patches of relative fertility. From this basis, they developed 14 propositions to characterise and explain the ecology. They revisited this framework in 2011, with some modifications to their original scheme, and further noted that some characteristics of arid Australia were broadly similar to those of arid environments on other continents, some features were accentuated in arid Australia, and some features were markedly dissimilar to those of arid environments elsewhere. Collectively, these propositions provide a substantial conceptual model of the ecological workings of the arid – and to a large degree, the semi-arid – Outback.

A dry lake bed near Kings Canyon in the Northern Territory typifies the boom–bust cycles of the Outback.

Proposition	Notes
1. Rainfall is especially unpredictable in arid Australia	All desert systems may have irregular rainfall patterning, but rainfall in Australian desert environments is particularly erratic.
2. Big rains structure ecosystems	Heavy rainfall events dramatically alter physical environments and may stimulate episodic recruitment for many species
3. An infertile well-sorted landscape	Australian soils generally are poor in phosphorus and nitrogen, but there is a marked contrast in nutrient availability between run-on and run-off areas.
4. Soil moisture shapes the spectrum of plant life history strategies	Temporal patterns of soil moisture in Australian deserts have resulted in a distinctive spectrum of life histories and forms.
5. Fertility controls digestibility	Low-nutrient soils favour longer leaf life spans, and such foliage tends to be less digestible to herbivores, with this trait particularly pronounced in vegetation in areas with lowest-nutrient soils, including spinifex (hummock) grasslands, mulga shrublands and chenopod shrublands.
6. Carbohydrates are plentiful	In order to extract sufficient phosphorus on nutrient-poor soils, plants draw and produce 'excess' carbohydrates, which may benefit some consumers. Also, abundant carbohydrates and long lifespan for leaves may produce relatively high standing vegetation biomass, and this may fuel extensive fire.
7. Fire is a powerful influence	Fire is of particular influence in Australian deserts because of high biomass of perennial plants and slow rates of decomposition. Fires may 'unlock' nutrients, and succession (vegetation change with time since fire) helps to maintain plant species diversity.
8. On poorer soils, herbivores and detritovorous consumers are constrained by indigestibility and irregularity of production	In areas of infertile soils, herbivorous animals must survive on poorly digestible or very intermittent plant production, and consequently are typically either opportunistic (cued to ephemeral bursts of resources) or persistent and specialised. Because there is much indigestible plant biomass, much production is ultimately consumed by animals feeding on detritus (particularly termites).
9. On more fertile soils, herbivores and detritovorous consumers are constrained principally by irregularity of production	There are more consumers of vegetation in fertile areas. These show marked variation in abundance linked to rainfall-triggered plant production. Termites are less dominant.
10. Consumers of plant exudates are prominent	Because of 'excess' carbohydrate production, many plants in Australian deserts produce energy-rich products (including nectar, arils and manna). These serve to increase the diversity and density of social insects (including some specialised ant species), leaf-sucking insects (Hemiptera), and nectar-feeding birds.
11. Assemblages of higher-order consumers reflect infertility and irregularity of production	Food webs reflect patterns of water and nutrient availability. The physiology of birds and mammals limits their persistence in poorer landscapes, and in such environments the most abundant and diverse predators are invertebrates and reptiles.
12. Some consumers exhibit dramatic opportunism in response to irregularity of production	The Australian deserts present occasional pulses of resource availability, and many species use various strategies to benefit from these peaks (boom–bust cycles). This may be most accentuated for wetland species, but also involves many other species, with strategies including nomadism, opportunistic breeding, and high reproductive potential.
13. Consumer assemblages display underpinning stability within their dynamism	Not all is boom and bust; many species have relatively stable populations and largely invariant ecology.
14. Longstanding feedbacks between humans and environmental structure and function	Over at least 35,000 years, Aboriginal people have influenced environmental structure and composition, in seeking to enhance or at least stabilise resource production.

Table design by The Pew Charitable Trusts

Most natural ecological processes have remained largely intact and functional across the Outback, but this may change as increasing human pressures deliberately or unwittingly transform the ecological processes in such a manner that the systems themselves fray or change irrevocably.

The biodiversity and ecology of the Outback are not necessarily crisply distinguished from that of Australia generally. And there may be marked disparity in ecological characteristics between Outback regions, particularly between contrasting regions in the high rainfall monsoonal tropics and the arid centre. However, there are some key and relatively simple mechanisms that structure and define the Outback's nature. As with many areas, ecology in the Outback is a dance of the elements, particularly of earth, water and fire, operating over time and space.

Earth

Most of Outback Australia is an old landform and weathering over deep time has led to a relatively flat landscape and nutrient-poor soils. These two traits underpin much of Outback ecology. The relative topographic simplicity means that many ecological processes operate over vast areas, that there is no marked altitudinal zonation of local-scale climate, and that there may be few secure refuge areas. But this may also mean that where there are rugged ranges in the Outback, these may take on an ecological importance that belies their relatively low altitude. The flatness and apparent general homogeneity of the landscape may also mean that management factors that superimpose variability on it may have an important ecological role. Fire is the most notable of these factors, and an environmental mosaic that comprises many patches of land with contrasting fire histories may provide a far greater range of resources, and species diversity, than a comparable area that has been exposed to only one fire history.

The limited nutrients in Outback soils have many ecological ramifications. Many Australian plants have marked adaptations to extract and keep nutrients – they invest in extensive roots and form relationships with nitrogen-fixing bacteria and fungi, and they conserve nutrients through long-lived leaves and by manufacturing compounds such as phenolics and terpenes to deter leaf-eating animals (Lambers *et al.* 2006; Orians and Milewski 2007; Morton *et al.* 2011). Lack of phosphorous, in particular, has probably driven the evolution of sclerophyllous vegetation – the tough, evergreen leaves of eucalypts and banksias that are so distinctive to Australia. One important genus of plants, *Acacia* – the wattles, with more than 800 species – is notable because the plants themselves are nitrogen-fixers and they may facilitate conditions favourable for other plants that do not fix nitrogen, such as eucalypts (Orians and Milewski 2007).

Other requirements for plant growth – carbon dioxide and solar energy – are plentiful in the Outback and water is abundant either seasonally (in the north) or occasionally (in the Centre). The relative abundance of such resources, but not of nutrients, may mean that plants can manufacture a substantial amount of structural tissue including stems, branches and roots, and sugars, all low in nutrients. Such sugars are available to animals in flowers or from nectaries, or are extracted by animals from sap. Fuelled by abundant sugar, the world's largest and most plentiful nectar-eating birds are found in Australia. The liberal supply of sugar benefits plants: birds, bats and insects pollinate flowers and ants lured to nectaries fend off caterpillars and other animals that eat plants. Some Australian ants – including the edible honeypot ant – have developed specialised castes to store sweet liquids. Social insects such as ants and termites are therefore well-suited to environments where production is unreliable or of poor quality (Morton *et al.* 2011).

Many Outback plants are often too low in nutrients to sustain grazing animals except for brief periods after rain or fire. Particularly in more arid Outback areas, spinifex grasslands are the most phosphorous-poor vegetation in dry climates on Earth and are barely grazed, except during the first flush after fire (Orians and Milewski 2007). Because so little foliage is eaten, fuel for fires accumulates. Other nutrient-poor plant products – such as bark, tannins, volatile oils and resins – are also flammable and increase fire intensity once ignition is triggered. Fire is the major consumer of plant tissue over much of the Outback (Orians and Milewski 2007). Frequent, intense fires can perpetuate nutrient poverty by vaporising nitrogen faster than it can be fixed by plants and depleting other nutrients such as iodine and selenium (Orians and Milewski 2007).

Most of the nutrients in dry landscapes are within the top few centimetres of soil, and much may be concentrated beneath plant canopies (Eldridge *et al.* 2012). In a relatively infertile environment, the digging of some animals may be important in turning over this soil and re-distributing nutrients (Spotlight 4).

Spotlight 4 **The upkeep of Outback ecology: inputs from native animals**

People mostly think of natural environments as providing resources to animals. But animals also contribute in many ways to the structure, dynamics and productivity of environments; and the loss of particular animal species may have broad detrimental consequences for environmental functioning. One service provided by many animals in the Outback is soil turnover, resulting in enhanced productivity. For different objectives, many animals 'garden' the Outback.

Outback nights were formerly – and in some places are still – marked by energetic digging, with immense volumes of soil turned over and shifted by mammals building or renovating burrows and foraging for seeds, tubers, roots, soil animals or fungi. A single Bilby or Boodie (a rat-kangaroo) might excavate 30 tonnes of soil a year; a Woylie (another rat-kangaroo) might move six tonnes (Fleming *et al.* 2013). In the process, they mix, aerate and break down the soil, modify the topography and create pits that capture leaf litter, faeces, seeds and water. Because of the general scarcity of water and nutrients in arid environments, disturbances to the soil surface that create fertile patches can greatly influence the productivity and composition of plant communities. A study in the Arid Recovery reserve near Roxby Downs in South Australia found that there was 55% more mineralisable nitrogen in soils from the bottom of feeding pits than from nearby surface soils (James *et al.* 2009). More than 1300 seedlings from 46 plant genera germinated, in a glasshouse, from litter and soil taken from 90 pits but no seedlings emerged from 90 samples taken from areas next to the pits.

The Bilbies and Boodies responsible for creating many of the pits in the Arid Recovery reserve had been reintroduced and survive only because a fence now excludes foxes and cats. Most native digging mammals have disappeared over much of the Outback. Of 30 or so digging marsupials, six are extinct and at least 10 are threatened. (The losses would be even more if extinct megafauna, including the giant wombat *Phascolonas*, were considered.) Many native rodents – most of which dig – are also threatened. The Echidna is one of the few native digging mammals that has maintained its original range, thanks to abundant ants and termites and spiny protection that is partly effective against cats and foxes.

The most mysterious of Australia's diggers and probably the most subterranean of all mammals globally are the two marsupial moles of Australia's sandy deserts – the Itjaritjari and Kakarratul. They tunnel through lightly


Mike Gillam, Auscape International

A marsupial mole tracks across an Outback Australian desert. Two species of these distinctive creatures are restricted to the sandy deserts of the Outback. These species spend most of their lives underground and are rarely seen.

'cemented' sand dunes, backfilling as they go, preying on termites, ants and beetle larvae (Pavey *et al.* 2012). Because they come to the surface so rarely, almost nothing is known about them, but recent research has found some dunefields are riddled with their back-filled tunnels, totalling more than 30 kilometres of tunnel per hectare and suggesting a hitherto unrecognised abundance (Benshemesh and Schulz 2010).

Burrows and pits also provide shelter and safety from predators for a huge variety of non-digging animals. With Boodies gone from the Outback, except in a few fenced reserves, their relict warrens, some thousands of years old, might now house feral rabbits instead, which were greatly helped in their invasion of the Outback by ready-made burrows, especially in places with hard soils (Noble *et al.* 2007; Eldridge *et al.* 2012). These long-established burrows harbour other native animals, including Common Brushtail Possums, Echidnas, quolls, monitors (goannas), sand-swimmers (skinks) and beetles (Eldridge *et al.* 2012).

Some mammals, particularly bettongs and potoroos, dig in pursuit of truffles, the underground fruiting body of fungi. The fungal spores survive the digestive tract (and some have their dormancy broken) to be deposited elsewhere in nutrient-rich faeces. The decline of truffle-eaters means likely declines in fungi, with such decline in turn compromising plant productivity, for most trees and shrubs in the Outback have symbiotic associations with mycorrhizal fungi to increase their access to soil, water and nutrients (Vernes 2007).

Another benefit for plants provided by some digging mammals comes from seed caching. Some fruits or seeds buried by animals for later retrieval are forgotten and germinate away from their parent tree. The near-extinction of Woylies is thought to be one reason Sandalwood has low rates of regeneration in Western Australia (Murphy *et al.* 2005).

Many other animals – lizards (particularly goannas), frogs, beetles, spiders, termites and ants – also disturb the soil in ways that would influence the distribution of nutrients, water and organic matter in the Outback. Termites are one notable major player in soil processes – facilitating decomposition; regulating nutrient and energy flows; promoting soil formation, turnover and porosity; and influencing the distribution of plants and microorganisms. Land in poor condition has been associated with reduced richness and abundance of soil invertebrates (Dawes-Gromadzki 2005).

Termites, such as these Giant Northern Termites, play an ecologically important role across the Outback, consuming live and dead plant material and facilitating soil processes.

Of course, generalities brush over the subtleties, and in the Outback environment nuances may be critical. There are areas of higher fertility in most Outback landscapes, most extensively in the tropical floodplains of northern Australia, the Mitchell Grass Downs and in alluvial flats along watercourses. There are also many smaller patches of 'run-on' areas, including swales and around the base of ranges, which receive nutrients from upper slope 'run-off' areas. Collectively, these more fertile patches may have an importance that is disproportionate to their limited extent. For wide-ranging species, these relatively fertile areas may provide the highest rates of reproductive success ('source' areas) in most years. In drought years, when much of the landscape is incapable of supporting populations, these relatively fertile areas may offer a refuge that can sustain the species.

> The typically low-nutrient status of Outback soils constrains options for agricultural productivity, but doesn't necessarily constrain the richness of native plant and animal communities.

Many plant and animal species that are adapted to the generally low-nutrient Outback landscapes must be frugal most of the time, eking out relatively slow life histories (growing and maturing slowly, living for a relatively long time and producing few offspring). Limited nutrient availability also means that the Outback typically cannot support large populations of large animals: there is simply not the fertility to support the equivalent of Africa's large herds of conspicuous and charismatic large animals. However, invertebrates may be particularly efficient at harvesting limited nutrients, and high biomass, density and diversity of some invertebrate groups is a hallmark of many Outback environments.

Another consequence of the near-pervasive low-nutrient soils is that herbivorous species introduced to the environment may readily and rapidly deplete the nutrient capital. In a relatively few years or decades, unsustainable populations of livestock or feral herbivores may consume most or all of the available resources and render that area unusable for those native species that formerly subsisted there (Medcalf 1944; de Salis 1982; Riddett 1988).

The typically low-nutrient status of Outback soils constrains options for agricultural productivity, but doesn't necessarily constrain the richness of native plant and animal communities. This is because many Australian native plants have highly specialised mechanisms for efficient scavenging of sparse nutrients, while others use alternative pathways, symbiotic or parasitic habits, or associations with various micro-organisms, to overcome these deficiencies (Hamblin 2001).

Water

Water is the pivot of Outback life and its ecological functioning. It underpins human experience in the Outback and its land-use capability.

Climate conditions dictate that ecological systems work somewhat differently between the monsoonal tropics of northern Australia and the arid centre of Australia.

Northern Australia is characterised by a distinct seasonality, with relatively high and largely reliable rainfall occurring in the short summer wet season. This seasonality is 'arguably the most important environmental feature of northern Australia, driving biological processes operating at annual to evolutionary time-scales' (Bowman 2002). Many ecological processes work to a distinct annual beat and there is typically far more marked variation in environmental conditions within a year than between years. Despite the huge volumes of water falling in the wet season:

> Water is the pivot of Outback life and its ecological functioning. It underpins human experience in the Outback and its land-use capability.

Kerry Trapnell

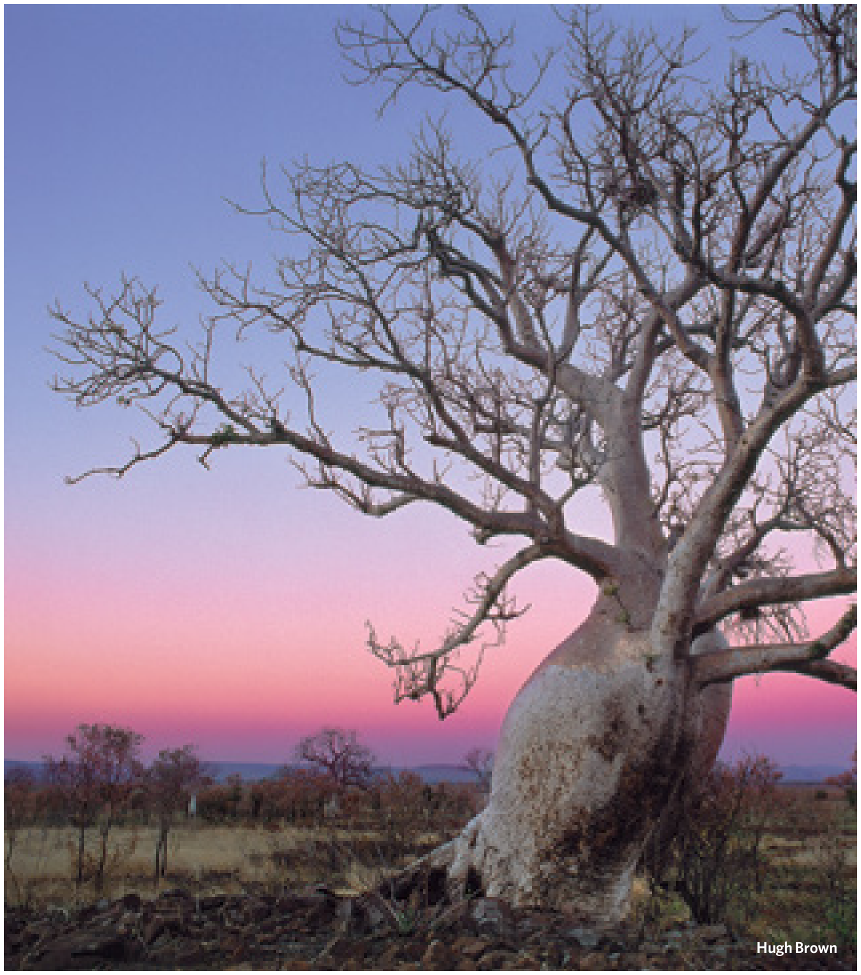
Like many Australian waterbirds Magpie Geese, depend on a range of different wetlands for their annual feeding and breeding cycles. This nest is on a floodplain on Cape York Peninsula, in far north Queensland.

' … the north can be described as being water limited. This paradox arises for several reasons. Despite high rainfall from November to April there is almost no rain for the remaining six months. Evaporation and plant transpiration is so high throughout the year that, on average, for 10 months of the year there is very little water to be seen' (Northern Australia Land and Water Taskforce 2009).

Broadly, the wet season is a time of renewal; of very rapid growth in grass and the greening of vegetation; of flower, seed and fruit production; of streams, rivers and wetlands filling; of resource abundance and breeding for many animal species, particularly wetland species such as crocodiles, waterbirds, turtles, many fish and frogs. Although the wet season is a time of replenishment and plant growth, it is also a time of chaos, with cyclones and floods, and often heralded by spectacular storms and lightning-ignited fires.

The dry season is a contrast. Much of the grass dries and withers; some shrubs and trees shed all of their leaves; the wetlands and streams contract and dry; many resources diminish; some animal species (including freshwater turtles) become inactive but others (such as many seed-eating birds) use this period for breeding; and the dry conditions facilitate frequent fire.

This is an extremely dynamic environment, and all plant and animal species of tropical northern Australia must cope with this environmental oscillation, by growing, building condition and reproducing in the short period of good times and by surviving through the long lean periods – or by ensuring that they leave progeny that will replace them. Some animal species cope by switching diet, some by moving out of the region during the dry season, some by working the landscape mosaic to track the shifting availability of food resources, and some by shutting down. Of course, some landscape positions are more seasonal than others: the floodplains and rounded hills



Parry Lagoons Nature Reserve in far north Western Australia is shown here in stark contrast: during the lush wet season (left) and the late dry season (right). Distinctive endemic boab trees have adapted to the boom–bust conditions. The Reserve is listed as a wetland of international importance under the Ramsar Convention.

may be particularly exposed to seasonal variation, whereas in the more rugged ranges, springs and narrow sheltered gullies, canyons and gorges may offer at least some moderation, and these areas may act as critical refuges for those species that are ill-adapted to climatic extremes.

Seasonality is the primary driver of ecological processes in large tropical rivers (Douglas *et al.* 2005). Most of the annual flow occurs within a three-month period, followed by a long period of little or no flow (Cresswell *et al.* 2009). Regular seasonal overbank flooding, occurring when it is warm, drives great bursts of productivity (Douglas *et al.* 2005). During the dry season, surface water becomes restricted to a few permanent or semi-permanent water holes and streams, mostly fed from underground aquifers.

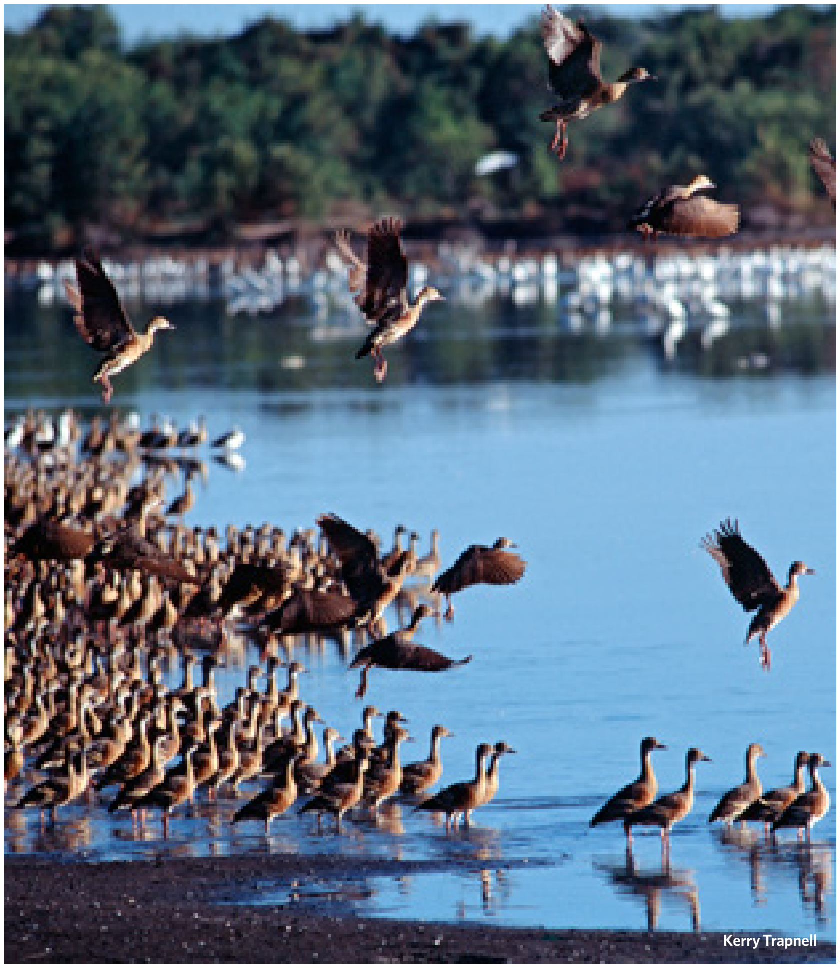
Although generally the cycle is reliably annual, the length of the wet season, total rainfall and patterning of rain days are highly variable in northern Australia. This poses great risks for species whose survival through the dry may be on a knife-edge, or those associated with particular environmental conditions – for example, the timing and duration of floodplain inundation affects fish abundance and recruitment of snakes, rats and waterbirds (Madsen and Shine 1999; Madsen and Shine 2000; Whitehead and Saalfeld 2000). Colonies of Magpie Geese nest only once the floodplains have been inundated to a depth of 30 to 90 centimetres, but their nests are then susceptible to further flooding if rains persist.

In central Australia, in contrast to the north, ecological processes are profoundly influenced by and related to the more variable climate, with occasional major rainfall events interrupting many years of little or no rain. Many plant and animal species show adaptations to survival over the long dry periods and the ability to take the rare opportunities to benefit from rainfall.

The erratic, variable rainfall in the interior drives great fluctuations in abundance and distribution of species and largely determines their life history strategies (Stafford Smith and Morton 1990). Rain pulses provide intermittent opportunities for plant growth. For example, a 12-year study in western New South Wales found that ground cover varied through an El Niño/La Niña (dry/wet) rainfall cycle from just 9% to 77% (Dawson and Ellis 1994). For some plants that regenerate only after high rainfall, many years may separate regeneration events (Watson *et al.* 1997; Wiegand *et al.* 2004)

Occasional heavy rainfalls create an array and diversity of wetlands, some of them very extensive. An 11-year study of surface water found that the total wetland area in the drylands varied between years from about 3000 km^2 to more than 300,000 km^2 (Roshier *et al.* 2001a; Roshier *et al.* 2001b). The floodplain of Cooper Creek alone exceeds 100,000 km^2 (Kingsford *et al.* 1999). When big rains fall in the Lake Eyre Basin, over half a million waterbirds representing more than 50 species – some having travelled more than 1000 kilometres – gather to feed and breed (Kingsford 1995; Kingsford *et al.* 1999; Roshier *et al*. 2001a; Kingsford *et al*. 2010). Many fish species make similar extensive movements (Kerezsy *et al.* 2013). At such times, 'the waters of once-dry but now-flooded riverbeds, lakes and floodplains produce a pulse of productivity that at its peak seems inexhaustible' (Kingsford *et al*. 2010).

Although some lake inundations result from locally falling rains, much of the water in major flood events in the arid and semi-arid Outback arises from rain falling hundreds to thousands of kilometres away. The very shallow gradients of the Lake Eyre Basin, and most other arid Outback areas, mean flooding may be extensive and may take many months to travel from the source area to the end point of the catchment, giving rise to a complex, diverse and shifting patterning of wetlands along the catchment (Kingsford *et al.* 1999; Roshier *et al.* 2001a).



Outback wetlands are surprisingly diverse and extensive. With the decline of the Murray–Darling wetlands because of over-allocation of water for irrigation, many waterbirds depend inland wetlands for core breeding areas.

On rare occasions, following substantial rain in its catchment, the normally dry Lake Eyre (top left and right) becomes one of Australia's largest water bodies and one of the world's largest internally draining wetland systems (above).

The wetlands of the Lake Eyre Basin and other Outback arid areas are not simply occasionally and opportunistically used resources for waterfowl and other wetland species normally based in more predictably wet parts of Australia. Rather, they may be core feeding and breeding habitats for some waterbirds and other wetland species (Roshier *et al.* 2001a). This is particularly the case in recent years with marked declines in waterbird breeding in the wetlands of the Murray–Darling Basin, which have been reduced due to pressure from irrigation schemes.

In the normally dry lands, flooding rains also initiate successive cascades of population booms in a wide range of terrestrial plants and animals (Letnic *et al.* 2004; Letnic and Dickman 2005; Letnic *et al.* 2005; Letnic and Dickman 2006; Letnic and Dickman 2010). In such good times, these population booms may be fuelled by many species breeding opportunistically, with individuals rapidly becoming reproductively active and breeding repeatedly, with their young showing high rates of survival and rapid maturation. High population densities, and extensive areas transitorily supporting high resources, may then trigger widespread dispersal. One recent example was the movement of millions of native Long-haired Rats during the 2009–2011 wet years in the Channel Country.

While surface water from rainfall is variable, groundwater supplies are more reliable and many groundwater sources have been longstanding features of the Outback. Permanent springs and seeps in Outback Australia are vital refugia. Such sites also allowed permanent human settlement in central Australia even during the peak dry periods of the previous ice age. Palm Valley in the MacDonnell Ranges is one such place: its released water is tens to hundreds of thousands of years old and significant recharge of the groundwater system may not have occurred for 50,000 years (Wischusen *et al.* 2004). Components of the Great Artesian Basin were deposited from 200 million to 65 million years ago (Smerdon *et al.* 2012).

Fire

Fire has had a long history as an important ecological process in Australia. Regardless of human influence, its prevalence is an inescapable consequence of the climate and of the soils. The climate is, and has long been, conducive to it.

For millennia, Aboriginal people have used fires, and – until disrupted in much of the Outback by European settlement – prevailing fire regimes were mostly those orchestrated by Aboriginal management. Across most of the monsoonal northern Outback and in the desert country, this management mostly entailed the deliberate use of small-scale and relatively low-intensity fires, as a tool for hunting, for ceremony, for safety,

Fire is a pervasive ecological feature across much of the Outback and is particularly frequent in the tropical savannas of northern Australia, which are thought to be the world's most flammable ecosystem. Pictured, a wildfire on Strathburn Station, Cape York Peninsula, in far north Queensland.

> Typically, now there are fewer but more extensive and destructive fires, resulting in a more homogenous landscape, with a consequent decline in many plant and animal species.

for ease of movement and for demonstrating ownership and capability. Fires flushed out game and recently burnt areas were attractive to some plants and animals that were important food or 'bush tucker', and incidentally happened to favour some other non-target species. A network of recently burnt areas within a clan estate also served, in an otherwise relatively featureless landscape, to constrain the spread of, and break-up, unplanned fires.

With the disruption of intricate traditional management in many parts of the Outback over the past couple of generations, fire regimes – the scale, intensity and frequency of fires – have changed. Typically, there are now fewer but more extensive and destructive fires resulting in a more homogenous landscape, with consequential decline in many plant and animal species (Spotlight 5).

Spotlight 5 **Making fire work: the purposeful use of fire in the Outback**

Traditional Aboriginal life and land management relied on the active use of fire. This was a skill honed over millennia. Its operation was carefully structured by societal rules, its application was considered, and its use was triggered by a perceptive reading of environmental conditions. With consequential expertise, fire was used for many purposes, including to break up and bring variety to the landscape, thereby preventing destructive broad-scale fires. It was also used to improve habitat quality for some valued plants and animals, and to establish breaks around the perimeter of some sensitive habitats.

This tradition has continued unbroken in some areas (Yibarbuk *et al.* 2001). However, across most of the Outback, there has been a loss or hiatus in this traditional management. In parts of the western deserts (including the Great and Little Sandy Deserts), intensive and traditional Aboriginal fire management largely ceased in the 1950s. With that loss the mosaic 'grain' of burnt and unburnt areas changed dramatically. Based on interpretation of imagery, some of this change can be quantified. For example, in an area of about a quarter of a million hectares of the Western Deserts, the number of 'recently burnt patches' declined from 846 in 1953 to just four in 1981, and the mean burnt patch size increased from 64 hectares in 1953 to more than 52,000 hectares in 1981 (Burrows *et al.* 2000; Burrows *et al.* 2006). In this case, the loss of traditional management has resulted in a far more uniform environment: 'the desert had been transformed from a high diversity patchwork to a sea of spinifex grass interspersed with massive burns' (Bird *et al.* 2003).

By the mid-1980s, many Martu people returned to this Desert country and resumed traditional fire management. In this hummock grassland (spinifex) environment, recently burnt areas typically have an increased floristic diversity associated with many 'fire weed' plants. Martu people recognise and give name to spinifex habitats of different age since fire, with this classification reflecting their utility for foraging: *nyurnma* is a recently burnt area with no regrowth; *waru-waru* is a recently burnt area in which herbaceous plants are growing, typically after a rain event; *mukura* is an area in which those herbaceous plants have reached maturity; *mangul* describes an area in which the herbaceous plants are declining and spinifex is returning to dominance; and *kunarka* is an area dominated by very mature spinifex. The Martu people are keenly attuned to fire: 'most adults can recount when, where and by whom every fire was lit (with details of fire intensity and progression) over at least the three previous seasonal cycles within a radius of about 100 km' (Bird *et al.* 2005).

Bardi Jawi Rangers from One Arm Point on the Kimberley coast conduct burning early in the dry season, producing significant environmental benefits.

Viewed from the air, the mosaic nature of the Bardi Jawi Rangers' dry season burning is apparent.

Research has demonstrated that fire has an immediate benefit to Martu people, with women hunting for burrowing animals (mostly goannas) capturing 575 kilocalories (kcals) of food per foraging hour in just-burnt areas, appreciably more than the average of 409 kcal per foraging hour in unburnt areas (Bird *et al*. 2005). Furthermore, hunting success rates were highest in smaller (fine grained mosaic) fires (656 kcal per foraging hour) than in areas subjected to larger fires. But fire also has a medium-term benefit (providing seeds and fruits of early successional plant species, such as fruits from *Solanum* species and tubers from *Vigna* and *Cyperus* species in the one to two years after fire) and longer-term benefit (helping to increase overall landscape-scale habitat suitability for many vertebrate species that are important food sources).

> The Martu people are keenly attuned to fire: 'most adults can recount when, where and by whom every fire was lit [with details of fire intensity and progression] over at least the three previous seasonal cycles.'

Martu hunters use fire to increase their ability to find goannas and other foodstuffs. But the goannas themselves also benefit from fires, with the fine-scale patchiness and extent of borders between burnt and unburnt areas resulting in increased habitat suitability and in a net increase in their population size, notwithstanding hunting pressure (Bliege Bird *et al.* 2013). This conclusion derived from anthropological research is complemented by similar conclusions from research based on detailed studies of some individual animal species. A notable example from the Tanami Desert is that of the Mala (a hare-wallaby), which benefitted from small-scale fires because they increased the diversity of habitat and resources within its home range, particularly increasing the availability of some ephemeral plant species important in its diet (Bolton and Latz 1978; Lundie-Jenkins 1993).

With the cessation of traditional fire management in its desert home, the Mala population crashed to extinction in the wild. (Predation by cats almost certainly also contributed to this decline.) A broadly similar association has been demonstrated for the Bilby in the Tanami Desert, with a dietary preference for fire-promoted plants and an increased incidence at sites relatively close to recent fires (Southgate and Carthew 2006; Southgate *et al.* 2007). At a different time scale and in a different region, a food resource (grass seed) bottleneck for the Gouldian Finches occurs at the end of the dry season. This period of scarce food is lengthened if their home range has been entirely burnt or entirely unburnt, but is reduced if there have been more small fires at different times throughout the year (Woinarski *et al.* 2005). In other cases, patch-burning benefits not only species that are associated with recently burnt areas, but also species that depend on mature, longer unburnt vegetation where that patch-burning reduces the risk of extensive fire that would otherwise consume a very high proportion of long-unburnt vegetation (Letnic and Dickman 2005). A general conclusion from these studies is that with the cessation of fine-scale deliberate burning, the 'fine-grained mosaics easily dissolve leading to a decrease in biodiversity at the local scale' (Bliege Bird *et al.* 2008).

The highly erratic climate of the arid and semi-arid Outback predisposes the land to uncontrollable and destructive fires in the years immediately following high rainfall periods. But recent research has demonstrated that the traditional patchwork burning provides an effective buffer against this variability: fire scars in such managed lands remain small even at times when climate variation causes huge fires in similar but unmanaged landscapes (Bliege Bird *et al.* 2012).

A spinifex wildfire in the Homestead Creek area near Newman in the Pilbara region. Western Australia's Martu people use different names to categorise spinifex habitats, depending on when they were last burnt.

There are many comparable examples of biodiversity benefits arising from traditional fire management across the Outback, including in the monsoon tropics and for some plant species (Bowman and Panton 1993; Bowman *et al.* 2001; Vigilante *et al.* 2004). One notable example is the Partridge Pigeon, found in the savanna woodlands of the Top End and Kimberley. This species feeds on fallen seeds and nests in a rudimentary scrape on the ground. It forages most efficiently when the dense grass layer is removed by fire, but fire may readily destroy its nest contents and it is likely to be more susceptible to predation in burnt areas. Consequently, a traditional fire-management regime resulting in a fine-scale mosaic of burnt and unburnt areas is likely to be optimal, and the pigeon is likely to decline in areas from which fire is excluded or in which there is frequent extensive fire (Fraser *et al.* 2003).

Of course, any fire regime will benefit some species but not others; and some researchers have contested the proposition that traditional fire management resulting in a fine-scale fire mosaic will benefit biodiversity generally (Parr and Andersen 2006).

A Kaltukatjara Ranger prepares to drop aerial incendiaries as part of prescribed burning work with the Katiti Petermann Aboriginal Land Trust in the south-west Northern Territory. The area provides habitat for a number of nationally threatened species, including the Black-footed Rock-wallaby, Princess Parrot and Southern Marsupial Mole (Itjaritjari).

Fire is a complex factor. It is considered here as a significant ecological process and, in a later section, as a threat. All fires are different, all species and environments respond differently to fire, and responses vary over space and time. It is fire regimes – the patterns of fire across space and time, defined by variation in incidence, severity, timing, extent and scale – that shape ecosystems and species, not single fires (Woinarski and Legge 2013). Individual fires may be extensive, intense and destructive, but generally in the Outback fire regimes, rather than individual fires, matter most.

Broadly, and consistent with the most marked climatic contrast, the Outback is subjected to two very different fire regimes. In the lower rainfall Outback areas, there is an irregular regime of infrequent fire mostly occurring in the aftermath of good seasons (Edwards *et al.* 2008; Turner *et al.* 2008). In the monsoonal-influenced northern Outback, the typical regime in the dry season is of frequent fires, sometimes annual, and often every two to three years (Figure 29). Australia's tropical savannas have been recognised as 'perhaps the most extensive and flammable ecosystem in the world' (Liedloff and Cook 2007). In this region, grasses grow rapidly in the wet season, but become tinder dry during the long rainless season.

Fire is less frequent and regular in the dry interior because there is generally less vegetation to burn. Grazing, including by termites, generally keeps fuel loads low, except after successive seasons of rainfall (Hodgkinson 2002). Highly flammable spinifex grasslands – the most widespread plant community in the interior – produce enough foliage to fuel fires on average only every seven to more than 20 years, depending on rainfall and management (Edwards *et al.* 2008). In other dry habitats, mostly *Acacia* woodlands and shrublands, it usually takes decades for enough grass to accumulate to fuel fires, although this fuel accumulation rate may be appreciably faster where the introduced Buffel Grass has invaded (Friedel *et al.* 2006). In a seven-year analysis (1998–2004) of fire patterns across the arid and semi-arid Outback, 27% of the area burnt at least once (Turner *et al.* 2008).

> It is fire regimes – the patterns of fire across space and time, defined by variation in incidence, severity, timing, extent and scale – that shape ecosystems and species, not single fires.

For much of the Outback, limited topographic variability – flat lands with few or no natural firebreaks such as large rivers or tall mountains – also mandates that if fires occur they are likely to be extensive.

Fire is an ecological 'disturbance' that may promote landscape-scale diversity. Much of the ecological pattern of the Outback is fixed in space, by underlying geology, soils or topography, but fire offers the opportunity to impose another more dynamic variability in resource distribution and diversity. Some plant and animal species, particularly those that disperse readily and have 'rapid' life history traits – maturing early but with a short lifespan and high reproductive outputs – prefer recently burnt areas. These areas may offer a short-term nutrient burst, a clear space free from competitors, or an open area with easier hunting or harvesting, and sometimes they support a temporarily abundant post-fire food resource. Conversely, other species – typically those with longer lifespans and slower maturation, with lower reproductive output, or susceptible to predation – prefer or require areas that have been long-unburnt. For example, many plants are much affected by the length of time between successive fires. If the interval between fires is too short, some plants may not be able to mature and produce seeds to provide for post-fire regeneration (Russell-Smith *et al.* 1998; Russell-Smith *et al.* 2002; Russell-Smith 2006). Broadly, landscapes with more complex mixtures (fine-scale mosaics) of unburnt and burnt patches, and with varying periods since fire, may support a higher diversity of species than more homogenous landscapes. This is because fire-driven habitat variability increases the chances that most species will have some habitat favourable to them at any one time. However, the evidence for this 'pyrodiversity-begets-biodiversity' concept is limited in some parts of the Australian Outback (Spotlight 5).

The detriment or benefit to environments and species associated with these regimes is influenced by the typically interrelated factors of the intensity at which such fires burn, the extent over which they burn, the patchiness of the fires (the number and size of unburnt patches within a fire perimeter) and by the length of time between successive fires.

The dichotomy between fire as a valuable or influential ecological process and as a threat arises because fires may occur – or be made to occur – as very divergent regimes. Many species and environments may cope readily or be at least partly dependent on a particular regime, or range of regimes, but will be seriously disadvantaged by other fire regimes.

Boom–bust strategies

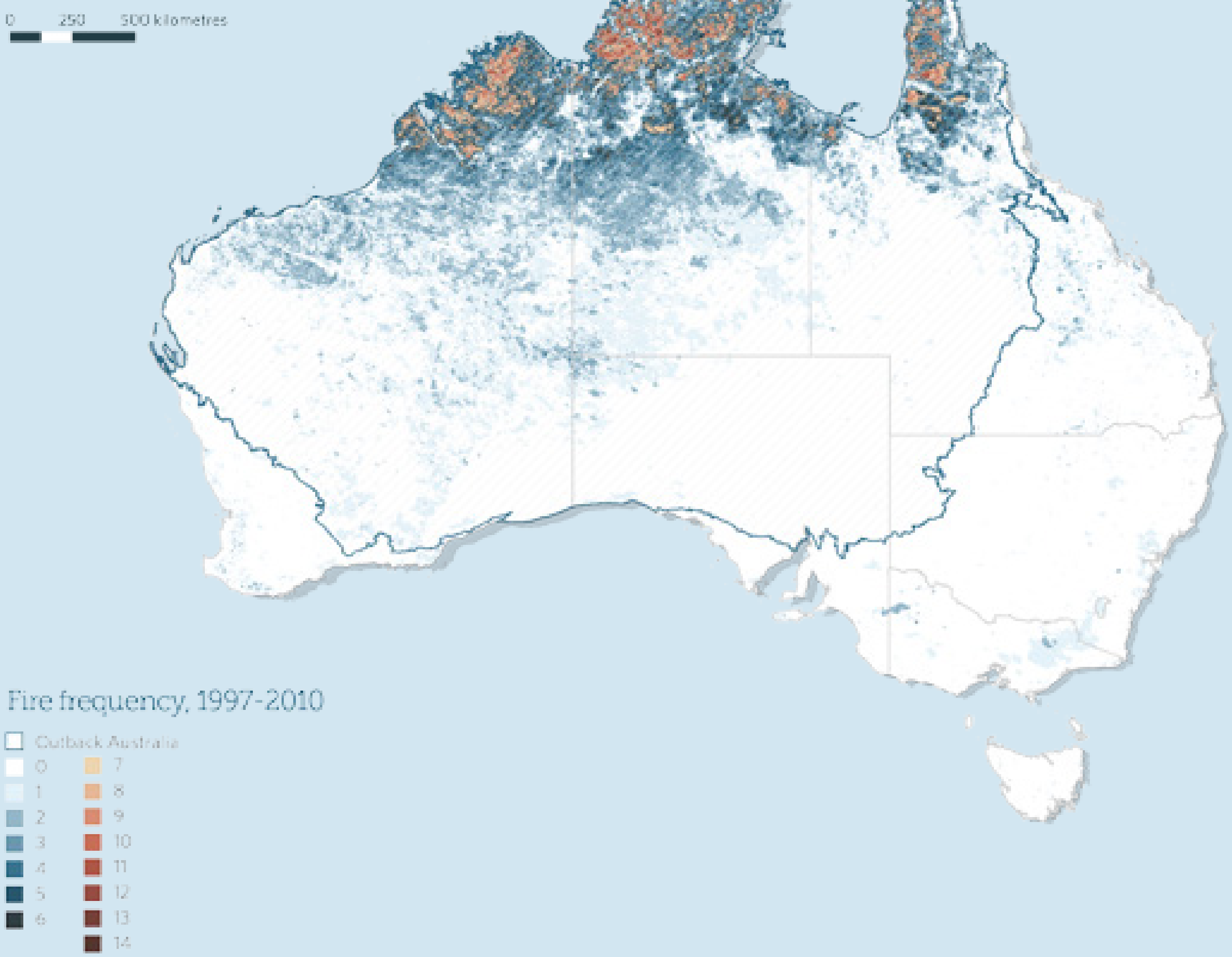
It is not straightforward to survive, let alone flourish, in environments characterised by the marked seasonality of the monsoonal tropics of the northern Outback or by the erratic climate of central Australia, and this challenge is exacerbated by the generally low nutrient status of soils. For the boom–bust, also known as pulse-reserve, environments of arid and semi-arid Outback Australia, plants and animals adopt a range of adaptive strategies (Letnic and Dickman 2006; Stafford Smith and Cribb 2009):

Figure 29

Variation in Fire Regimes Across Australia

Fire frequency over a 12-year period

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: degree



Source: Based on data from WA Landgate, modified by North Australian Fire Information service

Figure design by The Pew Charitable Trusts

- **Nomadism**. Nomads move from one burst of rain-driven growth to another, and hence must be able to disperse easily: examples include the Budgerigar, chats and some waterbirds.
- **Exploitation (opportunism)**. Such species spend the lean times elsewhere, for example in more resource-stable temperate Australia, and move into the arid and semi-arid areas only during boom times. As with nomads, such species must also have substantial dispersal ability. The pre-eminent example in the Outback is the Banded Stilt (see Spotlight 6).
- **Refuge specialists.** Such species persist in the arid and semi-arid Outback by staying in refuge areas, which are unusual in that resources are available on a relatively constant basis. Examples include River Red Gums growing on a permanent water table, fish in artesian springs or permanent water holes, and cycads on shady sides of gorges.
- **Ecological generalists.** Some sedentary animal species may persist in boom–bust environments if they can harvest whatever resources are available at any time, for example by switching diet. With a broad diet that partly tracks the shifting availability of different foods, the Dingo is an example of such a species.
- **Harvest and store.** Some plant and animal species in the Outback 'harvest' resources, effectively storing the surplus during good times. Examples include Honeypot Ants, the many mammal species such as dunnarts and rock-rats, and gecko species that store fat in their tails, and termites with their complex social colonies and food-storage strategies.
- **Shut down and wait**. Many largely resident Outback plants and animals endure or effectively shut down during the bust times and respond to boom times by growing fast and/or investing in seeds, spores or eggs. Examples include shield shrimps, locusts and burrowing frogs.

Some species exhibit elements of more than one of these strategies. The Long-haired Rat endures the dry times in limited locations within relatively fertile and stable refugial areas in the semi-arid Outback. Following good rainfall, it rapidly increases in population size and disperses widely across much of the Outback.

With less scope for directed dispersal, plants may have fewer options than animals. Perennial plants use pulses to invest in roots to maximise their potential to continuously access water and nutrients, while ephemeral plants invest mostly in leaf rather than roots, growing rapidly during the wet periods and dying after seeding heavily. There are many variations between these two extremes (Stafford Smith and Cribb 2009).

The Boab trees of the Kimberley region probably arrived from Africa as seeds floating over the Indian Ocean. They have since evolved into a distinctive Australian species that forms a memorable part of the Kimberley landscape. Boabs are valued by Indigenous people for their edible fruits, medicinal uses and water-holding properties.

Spotlight 6 **Inland waterbirds: water-dependent species in a dry land**

Life is a lottery. In highly predictable and relatively invariant environments, life can be ordered and relatively risk-free. This is not the general way of the arid and semi-arid Outback, where short, irregular periods of plenty provide chaotic punctuation to long background stretches of dearth. This is most evident for wetland systems and wetland-dependent species. Yet, somewhat strangely, there is a rich and distinctive set of plants and animals associated with aquatic systems in the dry Outback. Such species broadly show two patterns of existence. Some species minimise the unpredictability risk by associating closely with, and adapting to, permanent water sources, such as mound springs in the artesian basin, permanent springs and pools in gorges, and subterranean water sources. But such sites are typically pinpricks in the vast and otherwise inhospitable Outback, and the species associated with them may hence be highly localised and have small populations. This makes them exposed to substantial risks of extinction when those individual isolated sites are degraded.


Amanda Keesing

The breeding patterns of Banded Stilts rely on sporadic inland rains filling usually dry salt lakes such as these in Western Australia's Great Western Woodlands. Major rains trigger mass nesting events that may occur many years apart, and stilts fly thousands of kilometres to join them.

Many other species instead are broadly distributed, but capitalise on bursts of productivity in the infrequent wet periods and eke out an existence in the intervening periods. This strategy becomes especially challenging as the bad periods persist over the lifespan of the individual plant or animal. Some species, such as brine shrimps, approach the challenge by simply sitting it out, becoming inactive, or aestivating. But even in their dormant state, these plants or animals may be susceptible to predation or other threats, and most species cannot shut down indefinitely. For species that cannot rely on dormancy, mobility is a key. They criss-cross the Outback to track sites made productive by patchy rainfall events, or they emigrate from the Outback to permanent water sources in more predictable temperate areas and return when conditions are more favourable. One Outback species, the Banded Stilt, is the extreme example of this latter strategy.

Stilts are elegant, long-legged, long-beaked smallish waterbirds. They are an odd group, with only seven species across the world, and the Australian endemic Banded Stilt is an oddity even in this group, being the only species in its genus. Early naturalists knew it as a reasonably abundant bird occurring in estuarine and saltmarsh habitats of southern Australia, but became increasingly baffled by its apparent avoidance of reproducing. It was first described in 1816, but it wasn't until 1904 that the first breeding was reported, in an ephemeral lake in inland south-western Australia. Other elements of its life history have been gradually discovered, and the species is now known to rely on sporadic mass nesting events triggered by the temporary filling of inland lakes and the resultant brief burst of mass production of aquatic invertebrates (particularly brine shrimps and other crustaceans). This makes for an unpredictable life, and there may be many years between breeding events: a comprehensive record of all known nesting records across Australia indicated that it attempted to breed in only 26 years since 1904, with at least two periods with more than 10 years between successive nesting attempts (Collard *et al.* 2013). In one of its main strongholds, the inland lakes of South Australia, no breeding was reported from 1930 to 1989 (Williams *et al.* 1998).

Somehow, the Banded Stilts know of the rain events that can trigger the filling of the inland Outback lakes, and at these times may fly thousands of kilometres from their coastal haunts to seize their fleeting opportunity to breed. Having often not bred for many years, and with the lake waters being ephemeral, breeding is synchronised and rushed: ' … breeding pairs are thought to mate en-route as their first eggs are laid almost immediately following their arrival' (Collard *et al.* 2013). Often their luck runs out: the waters rapidly recede and the lakes become dry again before nesting is completed; or sometimes the waters continue to rise, washing away their nests. Usually they nest in mass aggregations of tens of thousands of birds, with one estimate of a colony of nearly 200,000 pairs. Often such colonies are situated on small islands in the lake systems, as protection from foxes and other predators. However, the Banded Stilts are not the only waterbirds looking to exploit the opportunity. Recently, Silver Gulls (Australia's native seagull) have also made the inland journey to breed in the same locations as the stilts, and some of these instances have resulted in harassment or predation by the gulls of most stilt eggs or young. In one breeding attempt at Lake Eyre in 2000, gull predation was known to have caused the failure of 9000 of the 18,000 stilt nests, and only 322 stilt chicks were known to have been fledged. At a later nesting attempt that same year, all 4000 stilt nests were abandoned because of gull predation (Baxter 2003). In subsequent breeding attempts, managers have successfully culled gulls to allow stilts to nest successfully. Notwithstanding such help, the life-history strategy of the Banded Stilt is a major adaptation to the Outback environment, and one that makes the species especially susceptible to climate change and to degradation of the Outback water systems.

The Banded Stilt may be an extreme case, but many other wetland species, including fish and waterfowl, are also highly attuned to the Outback's boom–bust rhythm. One example of the nature of the system is the significant rise and fall of fish populations in some impermanent inland lakes. A notable case is that of Lake Eyre in 1975, for which an estimated 40 million dead fish were left on the receding lake's margins (Ruello 1976). Where once the inland waterways were seen as poor value for the continent's waterbirds, they are now recognised to be critical and dynamic resources for a large and diverse waterbird community (Roshier *et al.* 2001a; Roshier *et al.* 2001b; Roshier *et al.* 2008; Kingsford *et al.* 2010). Satellite tracking is beginning to reveal much of the way this ecology is played out in time and space, and the manner in which waterbirds perceive this vast and dry continent as the backdrop for a distinctive, rich and reticulated wetland system (Roshier *et al.* 2001a; Roshier *et al.* 2006; Roshier *et al.* 2008). It is a system that nuances, and must nuance, the simple boom and bust to create diverse spatial and temporal opportunities. Some catchments receive rain and flood, but others don't. The low gradients and extensive reaches of inland rivers may lead to flood fronts taking months to reach their terminus. Species and resources, such as aquatic vegetation, invertebrates and fish, respond at different pace to the same rain and flood events (Roshier *et al.* 2002), in part reacting to changing salinities, depths and temperatures of water bodies (Williams *et al.* 1998). For wetland species that can move across this landscape, there is much variability in space and time to exploit as suitable patches transform kaleidoscopically. For such systems, all elements are important and survival strategies will fail if only some fixed parts are retained and protected (Kingsford 2000; Roshier *et al.* 2002).

The banks of salt lakes in the Great Western Woodlands, near Kalgoorlie, become densely packed with Banded Stilt nests during intensive breeding seasons.

Dispersal and linkages

Because of the extreme variability in productivity in drylands and savannas, many animals must migrate or disperse during at least part of their life cycle, or in response to seasonal or unpredictable climatic events. (Some plants do likewise in a less directional manner through wind or water dispersal or hitching rides on animals, and many use long-distance dispersal effectively to colonise new areas.) This dispersal may occur over vast or restricted scales within the Outback, or between the Outback and other parts or Australia or other continents. Much of this dispersal relies on continuity between patches of suitable habitat, or at least on breaks between suitable habitat being less than the ready dispersal distance of the organism (Roshier *et al.* 2008; Kingsford *et al.* 2010).

Some dispersal is regular, consistent and strongly directional, most notably in seasonal migrations, such as those made by bird species that move between the Outback and Asia. Examples include many shorebirds, Eastern Koel and Rainbow Bee-eater. There are probably regular migrations of some species within the Outback and between Outback areas and the rest of Australia, but there is generally little knowledge of such movement patterns. Many seabird species breed on islands and mainland sites around the Outback coast, then disperse regularly to favoured feeding areas, or irregularly in the non-breeding season. Loggerhead Turtles provide a similar example, breeding on beaches of north-eastern and north-western Australia, with at least part of the population then dispersing to feed in coastal waters of northern Australia. Barramundi and other fish species may make movements between rivers and the sea associated with breeding and life stage. For example, females of the threatened Largetooth Sawfish give birth in estuarine waters, and juveniles then disperse upstream to freshwater reaches, where they spend four to five years before dispersing to coastal and marine waters (Thorburn *et al.* 2007).

Other species disperse annually, but spatially more diffusely: a notable example is the broad-scale movement of many Black Kites and some other raptor species from lower-rainfall areas to the monsoon tropic in the dry season and their return in the wet season. Many nectar-feeding birds and flying-foxes may make broadly regular annual movements around the Outback to track the location of patches of flowering trees, but there is not yet a clear understanding of such pathways (Palmer and Woinarski 1999; Woinarski *et al*. 2000). Some other species, including the Australian Bustard, Emu and Red Kangaroo, make irregular movements across Outback regions, but these movements are purposeful, tracking vegetation responses to fire and rain (Ziembicki 2009). Even very small non-flying animals may undergo such dispersal: for example, individuals of the Lesser Hairy-footed Dunnart, a mouse-sized carnivorous marsupial, may move at least 10 kilometres to seek productive patches (Dickman *et al*. 1995).

The Australian Bustard is a characteristic species in many Outback areas. Like many other animals, it moves seasonally to follow vegetation growth after fires and rain.

For many other Outback species, dispersal is far more mercurial and is marked by occasional bursts of broad-scale movements and population increases after good rainfall, and then retraction and disappearance from large areas. The most notable examples of such irruptive species include waterbirds, Plague Locusts, Budgerigars, Flock Bronzewing Pigeons, Letter-winged Kites and Long-haired Rats (Figures 30, 31). Some irruptive species are normally extremely rare and localised – indeed, their poor-season refugia may be largely unknown. Also, the occasional episodes of irruption may provide an eagerly sought spectacle and an unusual opportunity to learn about facets of their ecology. A recent example is the irruption of the little-known Princess Parrot out of its poorly defined core range deep in the desert country (Pavey *et al.* 2014). Australian birds, particularly those of the Outback, are unusual globally in the extent of their opportunism, irruption and nomadism (Schodde 1982). Close to half (46.5%) of breeding birds in the Australian arid and semi-arid areas are fully or partially nomadic, the highest proportion of any region in the world (Dean 2004).

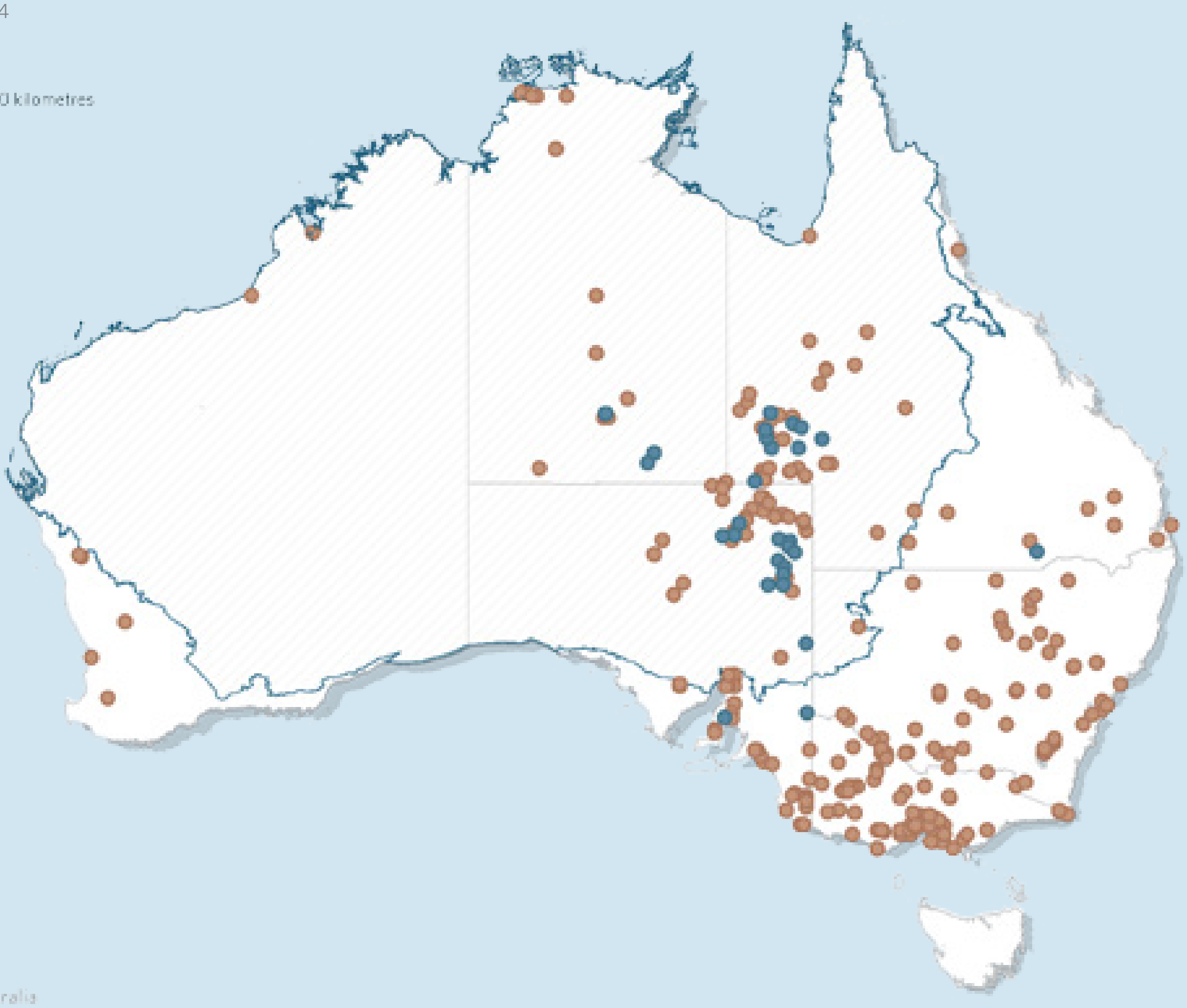
Figure 30

The Letter-winged Kite

An Outback species with dynamic distributional patterns – recorded in outbreak years in the 1970s and years of normal distribution in the 2010s

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: degree

0 250 500 kilometres



Outback Australia
Letter-winged Kite records, 1970-1980
Letter-winged Kite records, 2010-2014

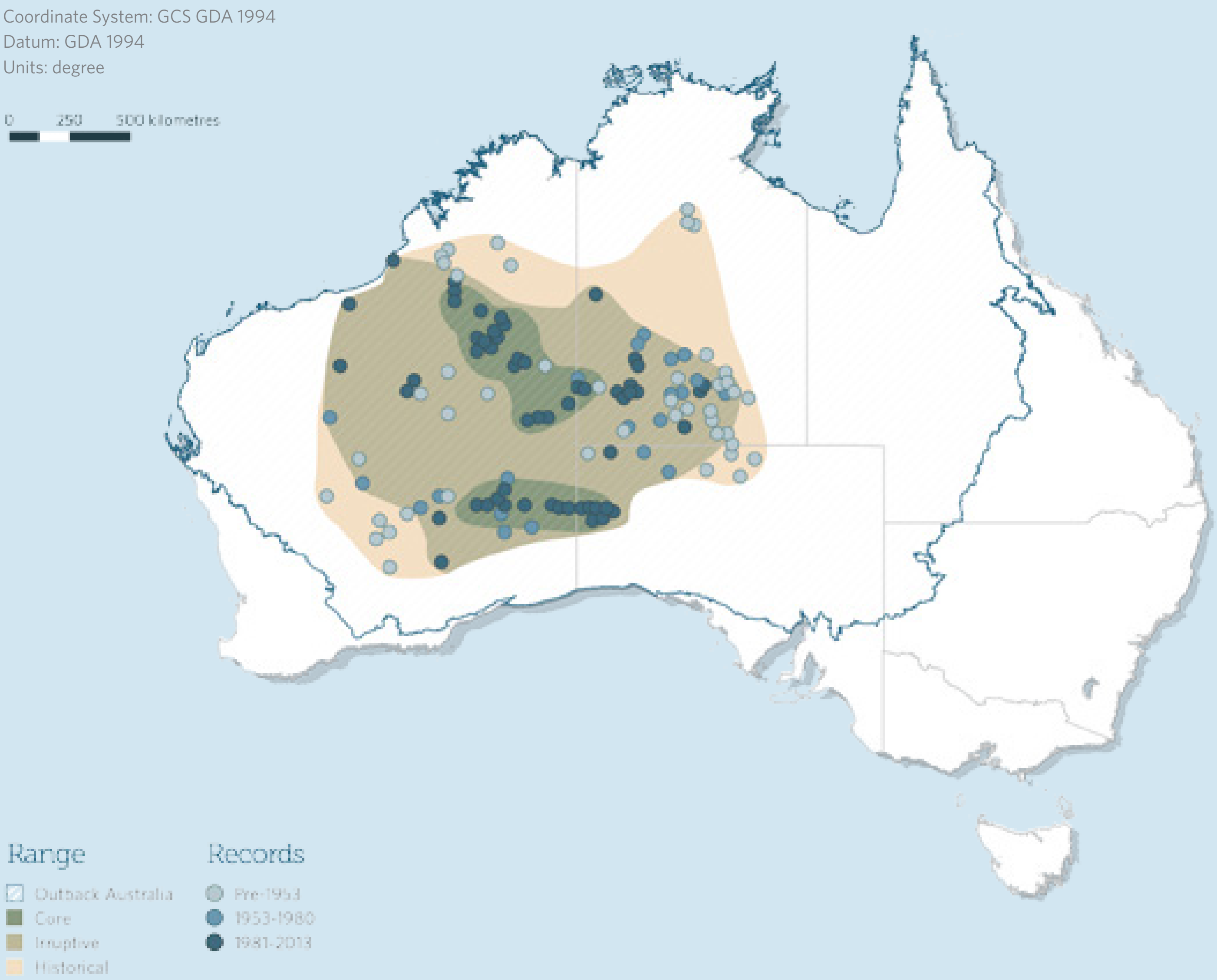
Source: Atlas of Living Australia

Figure design by The Pew Charitable Trusts

Figure 31

The Princess Parrot

Records of an Outback Species With Dynamic Distributional Patterns



Source: Pavey CR, Nano CEM, Cole JR, McDonald PJ, Nunn P, Silcocks A, Clarke RH (2014) The breeding and foraging ecology and abundance of the Princess Parrot, Polytelis alexandrae, during a population irruption. *Emu* 114, 106-115. (http://www.publish.csiro.au/nid/96/paper/MU13050.htm).

Figure design by The Pew Charitable Trusts

A consequence of this varied patterning of movements of many Outback animals is that the species composition at any site may vary markedly across different time scales (Barnard 1925; Pavey and Nano 2013; Wardle *et al.* 2013).

> The conservation of mobile species requires protection of all major habitats and sites required by the species during its dispersal process, as well as links between such sites.

The high incidence of dispersal and its varied patterning in the Australian Outback fauna presents a challenge for conservation management. The conservation of mobile species requires protection of all major habitats and sites required by the species during its dispersal process, as well as links between such sites (Soulé *et al*. 2004). In particular, protection is required for core refugial sites or habitats that provide resources for mobile species during times of stress, such as droughts (Morton *et al.* 1995a). This is a challenging task because many movement routes and refugia are poorly known, important sites may vary between seasons and years, and there are likely to be substantial differences among species in how they use the landscape. For all dispersive species, it is important to maintain broad-scale habitat protection and connectivity.

The challenge for such species, and for species not generally regarded as highly mobile, will be exacerbated with climate change. Effective conservation must protect landscapes to allow for long-term changes in the range of species. With climate fluctuations, 'no one place can be considered permanently occupiable by some plant and animal species' (Morton *et al.* 1995b). It requires protecting habitat diversity at small and large scales, maintaining habitat connectivity, and protecting and bolstering refuge areas.

Refugia

Refugia are those places where animal and plant species may persist relatively securely during periods in which one or more factors render survival in most parts of their range challenging or unlikely. They are areas or habitats that components of biodiversity can retreat to, persist in, and expand from under changing environmental conditions (Keppel *et al.* 2012).

Refugia may operate annually: for example, across the dry season in monsoonal northern Australia, at least some invertebrate species may move from savanna woodlands to shelter in shady rainforests (Kikkawa and Monteith 1980). They may function over scales of decades: for example, for many species in central Australia they can provide refuge over the course of extended drought periods. They may operate over evolutionary time scales: for example, for the Brown Pine *Podocarpus grayae,* characteristic of more equitable and wetter climates, that has persisted in sheltered narrow gorges in small areas of monsoonal northern Australia across climatic oscillations over millennia (Woinarski *et al.* 2009). Refugia themselves may be diverse. They include islands, relatively permanent water sources, fire-protected areas, areas with marked altitudinal variation, deep humid caves, sinkholes, or rugged ranges that provide an unusually broad spectrum of microclimates. In some landscapes, conservation reserves may serve as tenure-constructed refugia if they provide effective amelioration of factors, such as vegetation clearance or commercial-scale fishing, causing decline across a species' broader range. Refugia may coincide for many species, but also occur in very different places for species with contrasting ecologies, size or life history. Some may be well-defined and permanent, and others may be diffuse, dispersed and cryptic (Byrne 2008).

Aquatic organisms may have particular challenges surviving long droughts. Some fish species persist in permanent and semi-permanent riverine waterholes (Fensham *et al.* 2011). Others may spread their bets, persisting in river systems without permanent waterholes if there is a geographic spread of long-lasting waterholes that never dry out at the same time, because even in a drought some part of the system may receive rainfall and run-off.

Refugia may provide an essential pivot for biodiversity conservation, because during some periods they may sustain in a small area most of the population of particular species (Pavey *et al.* in press), and because controlling at least some threatening factors may be more simple and effective in these restricted areas. In contrast, conservation effort undertaken for a particular species outside a refuge area may be doomed if that species would normally rely on retreating during inhospitable times to refugia, and these places have been degraded or lost. Because of their demonstrated historic ability to sustain biodiversity under adverse conditions, refuge areas are a priority for conservation under projected climate change (Keppel *et al.* 2012), but their function may not necessarily be guaranteed if the pace and extent of climate change are unprecedented.

At a broad regional level, major evolutionary refuge areas have been identified for semi-arid and arid Outback areas (Morton *et al.* 1995a), based largely on the occurrence of narrowly endemic and relict species. These evolutionary refuge areas include mound springs, islands and cave systems, but most are gorges and mountain ranges. Some of the more important ranges supporting refugia include the Central Ranges, notably the MacDonnell, Petermann, Mann, Musgrave and Everard ranges, as well as the Pilbara-Hamersley Ranges, the Gawler-Flinders-Mount Lofty Ranges, and the Selwyn Range. All have gorges and permanent waterholes, and today act as refuges for plant and animal groups that were presumably more widespread in wetter periods. In historical periods of generally less hospitable climates, the Pilbara Ranges, being close to the coast, would have been more thermally buffered, making it one of the most important Outback refuge areas (Byrne *et al.* 2008). Although the isolated Outback ranges may have provided refugia for many species over long periods of unfavourable climate, other species used idiosyncratic and diffuse refugia, and some taxa have occupied many disjunct refugia for very long periods, predating the extreme aridity (Pepper *et al*. 2011).

Another approach has identified shorter-term drought refugia through the use of satellite imagery to detect those places in the landscape that have most persistent productivity across periods of generally low productivity. For semi-arid and arid Outback areas, such areas have been mapped (Klein *et al.* 2009) (Figure 32), and these authors considered that sympathetic management of these areas was a core requirement for the conservation of biodiversity in continental Australia.

There has been no comparable, comprehensive assessment of refugial areas for monsoonal northern Australia. However, the major areas of deeply dissected ranges (across much of the Kimberley, and western Arnhem Land), rainforest networks (especially in parts of Cape York Peninsula), permanent wetlands, and major islands can be assumed to have significant refugial value for many species (Bowman *et al.* 2010a; Moritz *et al.* 2013).

Gold in the pan: localised riches

Refuge areas are an important part of a more generalised feature of the Outback, particularly in arid and semi-arid areas: that resources are patchily distributed. As a consequence, the ecology and management of very large areas are driven disproportionately by localised relatively resource-rich patches (Morton 1990; Stafford Smith and Morton 1990; Stafford Smith 2008; Stafford Smith and McAllister 2008). It has long been recognised that oases provide critical and distinct features in many deserts, but the ecological importance of localised patches appears to be even more pronounced in Australian desert systems, perhaps because they are generally of particularly low productivity.

Furthermore, the ecological contrast of isolated, resource-rich patches within a broader landscape of resource scarcity may be self-reinforcing, because the rich patches may disproportionately attract plants and animals that themselves 'engineer' or provide other inputs to that environment, such as by turning over soil or by depositing nutrients. They may thus render it of even greater relative productivity to the surrounds (James *et al.* 2009).

The ecological potency of localised resource-rich patches in Outback systems has been diminished, accentuated and redefined by human use of these systems. Many of the important high-productivity patches or permanent water sources have been identified by humans and stock, with grazing and other activities concentrated on them to such an extent that their ecological role has been reduced or subverted (Morton 1990).

Outback ranges feature gorges and waterholes that provide important refuge areas for plants and animals, particularly during the dry season or drought conditions. An example is Pitta Gorge, in one of the nation's most remote wilderness areas – Western Australia's Prince Regent National Park.

Figure 32

Ecological Refuge Areas in the Arid and Semi-arid Outback

Sites with regionally high primary productivity in generally least-productive periods

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: degree

Notes: Areas are identified from analysis of satellite imagery. This mapping enlarges the sites to be visible at this scale.

Source: From Klein *et al.* (2009)

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Figure design by The Pew Charitable Trusts

Some sites that formerly afforded shelter from fire and hence retained long-unburnt vegetation may no longer offer such protection, given the increasing extent and frequency of fires. The increased incidence of artificial water sources across most Outback environments has reduced the number and area of sites that are now water-remote and hence largely ungrazed by livestock and feral stock, to the detriment of grazing-sensitive plants and associated native animals.

Similarly, in Outback landscapes now characterised by the near-pervasive occurrence of feral cats and of the widespread presence of foxes in arid and semi-arid Outback areas, the increasing number of sites at which managers have fenced out predators are now critical for the persistence in the landscape of many native mammal species, and may become increasingly important for some bird and reptile species.

Ecological theory divides a landscape into areas that function as population 'sources', where population increases, with a surplus spreading into other locations, and remaining areas, which act as population 'sinks', in which in situ population growth is negative and needs to be bolstered by immigrants from source areas. If the number and size of 'source' areas diminishes, the landscape-scale population trajectory will decline and species will disappear over extensive areas.

The ecological characteristic of the importance of small, resource-rich patches in the wider landscape has similarities in human use of the Outback. CSIRO's Mark Stafford Smith notes this parallel explicitly:

'Several other types of important 'primary' resources are also polarised between large 'infertile' areas with scarce occurrences and patches of high resources. These include minerals, tourism hot spots, surface water, and groundwater. Mining occurs on <1% of the Australian landmass (Beeton *et al.* 2006) (although there are exploration licences across nearly three-quarters of it). Almost all tourism outside towns in central Australia occurs on parks, <3% of the area of central Australia; in reality tourism activity is confined to a tiny proportion even of these – 40% of the visitor nights in the southern half of the Northern Territory (NT) are spent at one place, Ayers Rock Resort (around 900,000 visitor nights year, mean for 2004–06; TourismNT 2007). Only a small number of localities have a sufficiently large and reliable groundwater supply to permit irrigation exploitation, such as Ti Tree in the Northern Territory and the Carnarvon irrigation area in Western Australia. As a result, the human population and hence access to labour is also patchy' (Stafford Smith 2008).

Localised patches of relatively rich resources act as an ecological pivot to larger landscapes. These pivots are not necessarily tightly geographically defined. For some animal species, particular high-quality plant species such as Quandong act in much the same manner, providing a nutrient hit through their fruits, foliage, seeds or roots that is not generally available in the landscape, and which may tide those animals over lean times or form the basis that allows them to put on condition and breed successfully in good times. For the same reason, many of these key plant species are being grazed on selectively by livestock and feral animals, and have declined rapidly and extensively because of that intensive additional grazing pressure.

Barriers

Connectivity – the network of linkages among places – is a feature and functional foundation of Outback ecology and evolution, and of its social fabric. This connectivity may be especially pronounced in the Outback because of its relatively flat terrain, the near-continental length of some river systems, and the very gradational transition of its rainfall patterning and vegetation change – individuals of many species can ebb and flow over great distances.

Conversely, there are some natural features that inhibit or prevent dispersal for many species. An understanding of such barriers is needed to interpret the current distributional patterns of many species, the extent of endemism, current conservation opportunities, and the options for and likelihood of species persisting under changing climates.

> The greatly increased movement of people across Outback areas is now breaking down many long-established barriers and allowing for far more rapid and distant dispersal of many pests, weeds and diseases.

The most obvious such barrier is the sea separating the islands fringing the Outback coast from the mainland. But this has been an impermanent barrier, because lower sea levels for much of the past tens of thousands of years have meant that these islands were encompassed within the mainland. These *continental* islands generally support a subset of plants and animals typical of mainland areas. But the ocean barrier is important. The isolation of the main inhabited islands of northern Australia – for example in Torres Strait, Mornington Island, Groote Eylandt and the Tiwi Islands – has mostly led to distinctive and sometimes fiercely autonomous Indigenous communities and cultures. The ocean barrier continues to be a major logistical challenge for such communities. For wildlife, the ocean barrier may be a blessing as it may provide some protection from the otherwise pervasive spread of weed and pest species, and consequently many native plants and animals may now have greater conservation security on islands than on mainland areas. However, this refugial function of islands is readily broken where there is no effective quarantine. The greatly increased movement of people across Outback areas is now breaking down many long-established barriers and allowing for far more rapid and distant dispersal of many pests, weeds and diseases (Figure 33).

For many aquatic species, the divides between catchments are formidable barriers (Figure 34), and these have resulted in marked differences in species composition between the main catchment areas of the Outback. Recent analyses has revealed that the extent of these differences in species' composition, range and genetic distinctiveness is substantially greater than previously recognised (Kennard 2010). Of course, some aquatic species may evade these barriers by adopting a marine component in their life cycles, using subterranean water connections or occasionally being dispersed over longer distances by waterbirds or storms.

Many other barriers in the Outback are simply stretches of inhospitable habitat or climate that prevent the ready movement of plants or animals from one favourable site to another. The effectiveness, severity and duration of these barriers vary appreciably, as does their impact on plants and animals. At one extreme, a few kilometres of grassland or savanna woodland may stymie the dispersal of land snails from one rainforest thicket to a nearby one. At the other extreme, the Carpentarian Barrier, an area of relatively low rainfall between Cape York Peninsula and the Top End, has been a major biogeographic barrier that has long driven the divergence of plant and animal communities between these two regions.

Across arid and semi-arid Australia the many isolated rocky ranges are surrounded by a figurative 'sea' of lowlands that offer largely unsuitable habitat. Many of these ranges now support idiosyncratic compositions of species, or at least distinctive genetic forms of more widespread species. In some cases, this fragmentation may have been associated with the major period of development and spread of sandy deserts. However, recent research has suggested that for at least some groups the barriers have been longstanding and predate the spread of extensive desert conditions. For example, the genetic divergence that exists among *Heteronotia* geckoes living in different Outback ranges dates from about four million years ago, demonstrating remarkably enduring and effective barriers to dispersal for this group (Pepper *et al.* 2011).

Of course, the Outback's rocky ranges may be simply the most marked example of habitats that are now fragmented by contrasting habitats. For example, the Outback's major deserts themselves are now separated by habitats that are unsuitable for many desert species, and mound springs and rainforest patches are disjunct and isolated by habitats that differ markedly. These juxtapositions of suitable and unsuitable habitats have had substantial repercussions across the long history of evolutionary time for Outback biodiversity and they may become of even greater concern in the near future. With rapid climate change, these barriers may prevent species from moving to more habitable sites when their current habitats become climatically unsuitable.

Food webs

Nature is made up of species that interact with each other and with their surroundings. Even in some apparently simple Outback environments, these interactions can be potent and complex. It may be difficult to single out one species for conservation or management attention without referring to the constellation of other species with which it interacts. These interactions between species spin networks – including food webs – that allow multiple species to co-exist. These networks provide much of the form, function and resilience of ecological systems. Some interactions are obvious, simple and immediate, while others are varied and far more nuanced and may operate in an indirect manner. In the arid and semi-arid Outback, these interactions may be inactive over long periods but become strong ecological drivers following episodic rainfall events. Or they may operate in the reverse manner, becoming largely immaterial in times of plenty but having chronic impacts in lean times.

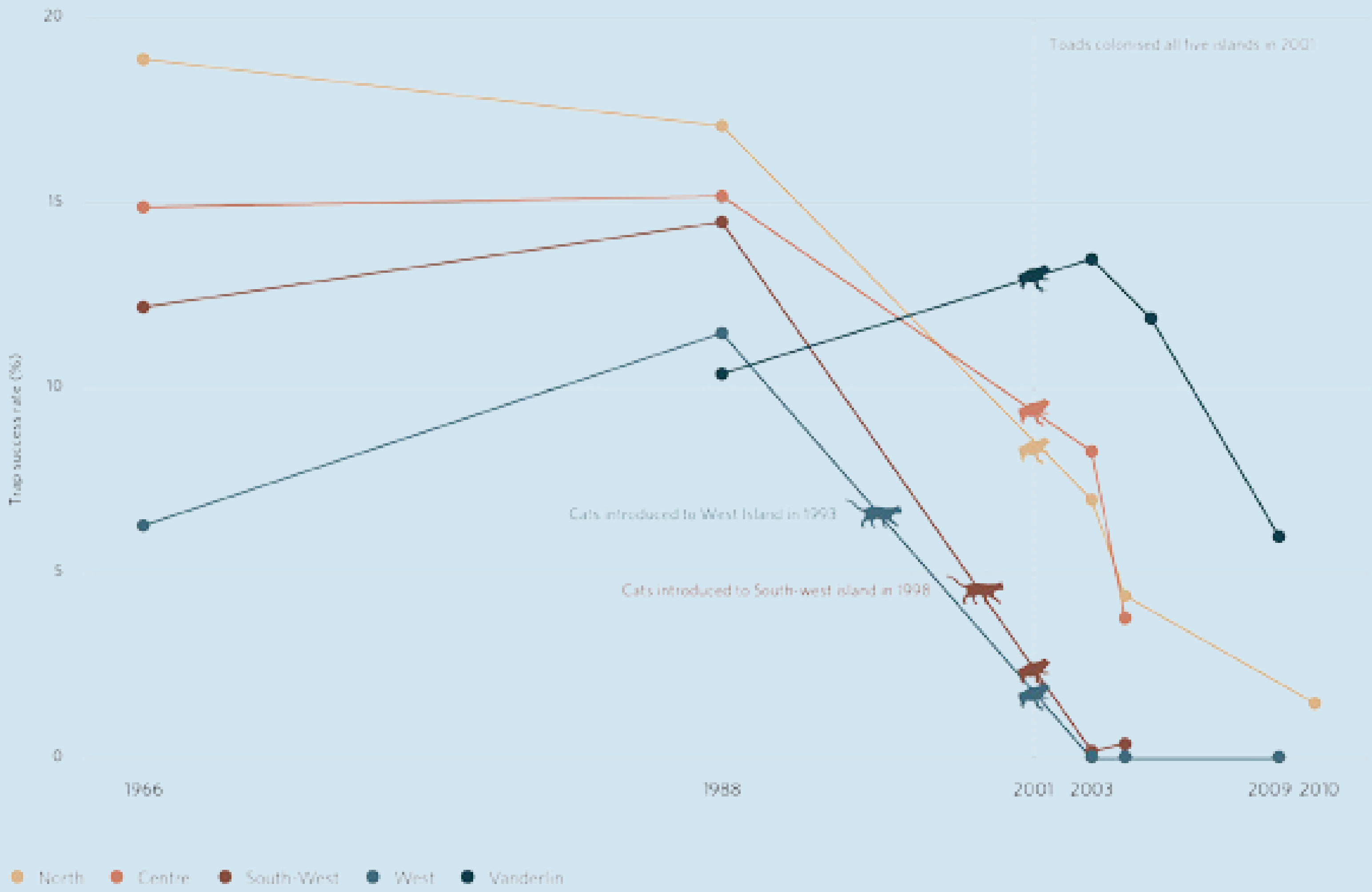
> Even in some apparently simple Outback environments ... it may be difficult to single out one species for conservation or management attention without referring to the constellation of other species with which it interacts.

The web of ecological interactions may be played out on micro scales – such as the relationship between individual plants and their associated mycorrhiza (fungi that may occur within or attached to the roots of plants and exchange carbohydrates from their host plant for minerals). Or it may extend to continental scales – such as the complex interactions between dingoes, feral cats and their native mammal prey (see Spotlight 7). Some ecological networks are hard-wired and durable, but others may be highly susceptible to change. The loss of a single species from established networks can subvert complex ecological equilibria.

Figure 33

Collapse of Native Mammal Fauna on Sir Edward Pellew Group

Introduction of a small number of cats (<5 founders) and the rafting of cane toads to five main islands blamed



Note: The left axis indicates abundance (% trap success) of native mammals sampled on six occasions over 44 years.

Source: From Woinarski et al. (2011b). Original copyright CSIRO 2011. Published by CSIRO Publishing, Collingwood, Victoria, Australia

Figure design by The Pew Charitable Trusts

Figure 34
Main Drainage Divisions Across Australia

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: degree

Source: Bureau of Meteorology

Figure design by The Pew Charitable Trusts

Spotlight 7 **Dingoes, and why bandicoots may have come to like them**

Predators exist in almost all ecological systems and they often perform an obvious ecological role in providing some regulation in the population size of their prey species. As prey species are often herbivores, the predators' influence may then extend to have repercussions to vegetation dynamics. A celebrated example that demonstrates this influence is that of broad-scale vegetation change across large areas of remote North America – notably including Yellowstone National Park – now recognised to have been caused by an increase in the abundance of large herbivores, with that increase triggered by a historic extermination of wolves. Recently, the managed return of wolves to these systems has succeeded in reversing that vegetation change, or beginning to reverse it (Ripple *et al.* 2001; Ripple and Beschta 2003; Smith *et al*. 2003). But large predators not only control the abundance of herbivores, and hence influence vegetation patterns – they may also moderate the abundance of smaller predators (and hence the abundance of other animal species preferentially preyed on by these) through competition or through predation.

Outback Australia has an odd assemblage of key mammalian predators. Fossil evidence indicates a long history of domination of the Outback, extending to around the time of Aboriginal entry, by very large reptile and flightless bird predators, and some impressive marsupials. The longest-lasting of these were the Thylacine and Tasmanian Devil, and cave paintings and mummified remains of these attest that they were widespread across mainland Australia until about 4000 to 5000 years ago. This date for their disappearance from mainland Australia coincides with the arrival in Australia of the Dingo, with genetic evidence indicating that the Australian

The Dingo is an important native predator, helping to control feral animals such as cats and goats in the Outback. This dingo was photographed in the Strzelecki Desert, central Australia.

dingo population arose from a very small number of individual dingoes introduced, presumably by sea-faring humans, from what is now New Guinea or the islands of eastern Indonesia (Savolainen *et al.* 2004). Many taxonomists accept that the Dingo, as a subspecies of the Grey Wolf (the ancestor of the domestic dog), now has an unusual distribution that includes remnants of its original range in south-eastern Australia as well as being found more extensively across Outback landscapes.

The mammalian predator regime in the Australian Outback changed again in the 19th century with the relatively rapid spread of the feral cat to extend over the entire mainland area by about 1890, and the spread of the Red Fox to extend across most of the mainland (other than the monsoonal tropics) a few decades later.

It is difficult to weigh up the relative impacts on the native fauna of dingoes, cats and foxes, for any losses of Australian native animal species caused by the Dingo probably occurred soon after their initial spread and the fossil record provides an imperfect documentation (Letnic *et al.* 2012a; Prowse *et al.* 2013). But it is reasonable to presume that until recent centuries, the Australian native fauna had come to a perhaps uneasy accommodation with dingoes. However, the more substantial impacts of the recently arrived feral cats and foxes are well demonstrated, and there is now ample evidence that predation by feral cats and foxes has been the primary cause of decline and extinction of many Australian native mammal species – particularly cat-meal-size species such as possums, bandicoots, larger rodents and small wallabies.

But food webs may have complex feedback loops, and the total predation pressure exerted by dingoes, cats and foxes is not simply the sum of the individual predation pressure exerted by these three species. Top order predators exert strong influence over smaller and less dominant predators: for example, dingoes kill cats and foxes, and cats and foxes seek to avoid areas regularly frequented by dingoes (Moseby *et al.* 2012).

> Recent studies have demonstrated that the abundance and persistence of threatened species such as the Bilby, Dusky Hopping-mouse, Yellow-footed Rock-wallaby, Malleefowl and Kowari are higher where dingoes are more abundant.

So, areas with intact dingo populations may be expected to have fewer foxes (and often also fewer cats) and consequently less predation pressure on those native species most hunted by these smaller predators. And, indeed, recent studies have demonstrated that the abundance and persistence of threatened species such as the Bilby, Dusky Hopping-mouse, Yellow-footed Rock-wallaby, Malleefowl and Kowari are higher where dingoes are more abundant (Letnic *et al.* 2012b). Although dingoes also prey on these mammals, dingoes are at much lower densities and the overall level of predation is lower.

However, dingoes have been persecuted or excluded from much of the Outback, mostly by pastoralists, and in such areas populations of feral cats and foxes have increased (a phenomenon labelled ‘meso-predator release’, with meso-predators being defined as smaller than, and subordinate to, top order predators) and the consequential high predation pressure has caused most severe declines in native fauna. Hence, somewhat counter-intuitively, the presence of dingoes has served to offer some protection to bandicoots and other native fauna. Indeed, some Australian ecologists now advocate returning the Dingo to a pre-eminent place in Australian ecosystems, as ‘the most significant constraint on the destructive power’ of foxes and cats (Johnson *et al.* 2007).

Furthermore, some animal species (mostly larger mammals) are preyed on more by dingoes than by cats and foxes, and culling of dingoes tends to lead to increases in these species. Unfortunately, many of these beneficiaries are introduced pests, such as pigs and goats, and native species, such as some of the larger kangaroos, whose ‘over-abundance’ may then cause additional detrimental impacts on native vegetation and compounding impacts on native animals, because the consequential reduction in vegetation would further expose some native animals to predators (Letnic *et al.* 2012b).

Dingo management in the Outback is contested, with many pastoralists concerned about stock losses due to dingo (and wild dog) predation, and consequently engaging in sustained control operations. However, some research indicates that such actions simply destabilise dingo social systems, and hence may lead to and reinforce abnormal rates of predation on stock (Wallach *et al.* 2009). Furthermore, a gradual retreat of sheep-pastoralism from much of the Outback may be slowly reducing the perceived need to reduce dingo populations.

6. People in the Outback

There are estimated to be more than 100,000 Aboriginal rock art sites in the Kimberley region, with only a small number of sites formally documented. This site, in Wren Gorge, features human figures painted on the red sandstone in what is known as Bradshaw style. The Bradshaw Paintings are dated to a minimum of 17,000 years ago.

6.1. A very brief history

Humans first settled the northern Outback more than 50,000 years ago and spread to the arid lands at least 35,000 years ago (Smith 2005; Smith and Ross 2008; Smith *et al.* 2008; Law *et al.* 2010). The cultures of Aboriginal Australians were and are diverse, as illustrated by the more than 200 different Indigenous languages across the continent (AIATSIS 2005; Australian Institute of Aboriginal and Torres Strait Islander Studies 2005). Within the broader regions occupied by these language groups were many thousands of individual clan estates, managed by landowners with specific responsibilities to their country. In many Outback regions, these connections and responsibilities to country remain strong. Through millennia of considered and careful activity, Aboriginal land management influenced the ecology of the country.

All Outback areas were occupied, but dispersion was uneven, with higher population densities in more productive regions, particularly of the northern coastline and more fertile river valleys. In the desert country, occupation and population size varied substantially with climatic fluctuations (Smith 2005; Smith and Ross 2008; Smith *et al.* 2008).

> There has long been a tendency to see potential (even when it was not there) and to seek to realise it: to tame and transform the wilderness and make it productive.

Subsequent to European settlement, land dispossession and other factors led to changes in Indigenous occupation of Outback lands. Some Aboriginal reserves were established, in lands not wanted for other purposes, and missions drew many Aboriginal people in from their more remote lands. Even if they remained on their country, working as stockmen or mining labourers, Aboriginal land management changed quickly in many areas settled by white Australians. The exceptions to these patterns were in the deserts of the centre and rugged parts of the north – areas unsuitable for grazing and ignored by selectors of pastoral properties. In those areas, Aboriginal people remained actively on the country living more traditional lifestyles well into the 20th century, although assimilation policies led to most people moving into more central settlements from the 1950s onwards. Since the 1980s, there has been some reversal of the previous trend, with increasing recognition of native title, Aboriginal acquisition of pastoral properties and establishment of outstations (small settlements on Indigenous land). However, this has not yet overcome the marked bias in land allocation:

'While there is no doubt that the Indigenous 'estate' is now considerable, most of the land that has been returned to Indigenous people since the 1970s is remote, inhospitable and marginal. The process of colonisation over two centuries ensured that the best land was granted, taken or purchased by non-Indigenous Australians. The Crown land that was still unallocated by the 1970s remained so for good reason' (ATSISJC 2007).

From the 1850s, the progressive wave of new white settlement moved in fits and starts as explorers, stockmen and prospectors progressively searched for two commodities: well-watered lands suitable for cattle and sheep, and gold. Most widespread and of most consequence was the search for pastures. Much of this exploration and settlement was unsuccessful and often the characteristics of the landscape and its environmental constraints were misread – wilfully, over-optimistically or naively – by those more familiar with, and wanting to reproduce, European systems. One example is Stokes' naming of the Gulf Plains of Queensland as 'the Plains of Promise', because:

' ... even in these deserted plains, equally wanting in the redundance of animal, as in the luxuriance of vegetable life, I could discover the rudiments of future prosperity, and ample justification of the name which I bestowed upon them. ... I could not refrain from breathing a prayer that ere long the now level horizon would be broken by a succession of tapering spires rising from the many Christian hamlets that must ultimately stud this country' (Stokes 1846).

Another example is of Stuart, in 1865:

'I have no hesitation in saying that the country I have discovered on and around the banks of the Adelaide River (near present-day Darwin) is more favourable than any other part of the continent. ... I feel confident that, in a few years, it will become one of the brightest gems in the British crown' (Stuart 1865).

The Outback puzzled many. There has long been a tendency to see potential (even when it was not there) and to seek to realise it: to tame and transform the wilderness and make it productive. Former Australian Prime Minister John Curtin considered it a national imperative:

' ...both for reasons of defence and development special attention must be given to certain parts of the Commonwealth in order to enable us to administer most effectively the total strength of the nation. Some of these parts are, as it were, vampires which at present are sucking at much of the nation's strength. We cannot retain empty spaces in the face of modern development and communication' (Curtin 1947).

A countervailing current saw much of the Outback as an irredeemable wasteland, unpopulated and of no possible use. Over the course of a five-year placement in Australia, the English geographer, John Gregory, coined the term that would define and deflate the Outback for decades, the 'Dead Heart of Australia' – those 'vast tracts of the interior, which are, at the present time, of no use for anything' (Gregory 1906). Similarly, the Australian geographer Griffith Taylor recognised that much of the land had severe constraints on land use potential and mapped its plausible population densities and use (Figure 38), in large part to counter unrealistic proposals to increase the Australian population to well beyond 100 million (Taylor 1926).

These varying perceptions of the Outback's environments, constraints and opportunities have coloured much of its history since European settlement began. They have led to some beneficial outcomes, but are also the root of many of the Outback's existing social, economic and environmental troubles.

Eventually, pastoralism extended over much of the Outback, in many cases beyond the bounds of logistical practicality or environmental sustainability. Production and profitability have ebbed and flowed, but many pastoral enterprises have persisted as unviable commercial enterprises long beyond the demonstration of perennial unprofitability (Holmes 1990).

Gold and other mineral wealth required more skill or luck to find than grass and water, but following the gold rushes in coastal New South Wales and Victoria in the early 1850s, prospectors fanned out over the continent. Rushes occurred in remote parts of all Outback states from the 1860s onwards including Halls Creek in the Kimberley, Kalgoorlie in the Great Western Woodlands, Coen on Cape York Peninsula, Arltunga in Central Australia, Pine Creek in the Top End and many others. The rushes created scrambles of thousands of people, many with little or no capital, and often unprepared for the rigours of remote life. Some fields were rapidly stripped of gold and the early towns faded back into the bush. Other districts, especially Pine Creek and the mining powerhouse of Kalgoorlie, retain active gold mines.

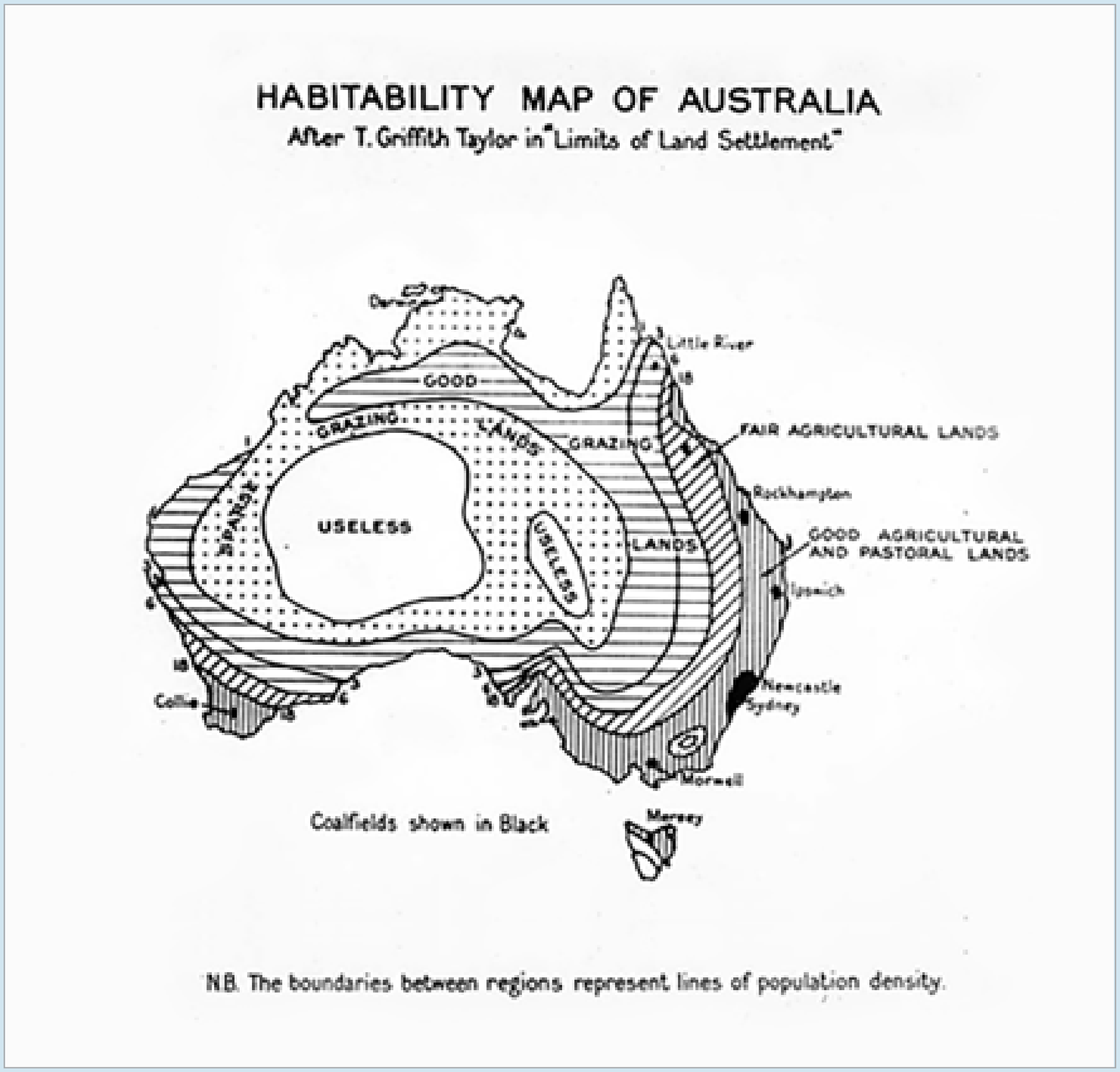
From the late 19th century, booming European and American industrialisation increased demand for other metals and major mining towns based on zinc, lead, copper and other metals were created. The extensive mineralised belts around Mount Isa, Broken Hill and Kalgoorlie were progressively discovered and opened up. Demand for oil and gas grew through the 20th century and fields developed in the Channel Country of South Australia and south-western Queensland, and in the Amadeus Basin west of Alice Springs. As prospecting and processing technology improved through the 20th century, new discoveries allowed large mines to be developed in remote locales, such as the Telfer mine in the Great Sandy Desert and the Granites Mine in the Tanami. From the 1970s, the huge iron ore mines of the Pilbara came progressively into production and in the 21st century new technology allowed coal seam and shale gas to be sought in many Outback regions. Some of the major mining developments have led to the development of substantial towns in remote areas, although in some cases the infrastructure and population associated with such development has been ephemeral and the towns have withered as mineral resources or profitability have declined.

Successful horticulture development has been limited in the Outback. Early European colonisation of Darwin and some other remote Outback outposts included trials of a range of crops, with subsequent hopeful and mostly doomed attempts at intensive crop production (Bauer 1977; Cook 2009). The most notable developments have been the Ord River irrigation projects from the 1960s and the incremental increase in crop production in the Darwin–Katherine region, mostly since the 1950s.

Parts of Outback Australia, particularly the monsoonal north, have repeatedly attracted visions for intensive horticulture and other development, often eagerly supported by governments. Most have failed,

Figure 35

Griffith Taylor's Geography of Opportunity in Australia



Note: Contours represent potential population density (people per square mile)

Source: Griffith Taylor (1926)

with substantial economic cost and residual and significant environmental detriment. There are recurring traits in this history (Davidson 1965; Bauer 1977; Woinarski and Dawson 2004; Cook 2009; Kutt *et al.* 2009):

(i) the proponents are mostly not from the area and have little familiarity with the environment and its constraints. This has contributed negatively to the attribution of value to these environments and their component parts;

(ii) the environment is seen to be uniform, undifferentiated and monotonous, such that trial areas can be readily scaled;

(iii) the environment is perceived to be so extensive and of so little value that little safeguard needs to be built into development proposals;

(iv) repeated development failure reinforces the perception that the land is of limited value, and hence few resources should be directed towards understanding it (or rehabilitating it after development failure);

(v) the environment is perceived to be so marginally productive that the only route to substantial profit is through intensive modification of the environment and large-scale development;

(vi) the economic framework supporting remote development is so tenuous that developers and their supporters (for example, governments) consider that development should not be burdened by substantial imposed conservation regulations; and

(vii) areas with high rainfall are naively considered to have a reliable and controllable surplus of water ripe for extractive use, and this resource is currently being wasted or unused.

There is a dogmatic theme in this visioning, that the land will unlock its bounty and be transformed into something useful, through the committed application of investment, vigorous and persistent activity, and technological capability. These development tenets have persisted notwithstanding clear evidence of repeated failures and the sober assessment of land resource experts:

'There is no comparable region in Australia where … man has so consistently overestimated the power of his technology in the field of primary industry to draw forth bounty from the land' (Lacey 1979).

'Failure was due to a fundamental lack of understanding of the limitations of soils and climate' (Fisher *et al.* 1977).

6.2. Current tenure, land use and governance

Tenure is complex in the Outback, and unique in the national context (Regional Australia Institute 2013). It is also not necessarily well-defined, either legally or geographically. The degree to which native title overlays different land tenures continues to be tested in the courts. There is no official, comprehensive and up-to-date national dataset that identifies Indigenous-held land across all Australian jurisdictions (Altman *et al.* 2007).

Pastoral land use – mostly as long-term leases issued by states on crown land – still dominates the Outback, with pastoral lands comprising about half of the area. Other major land tenures include conservation reserves (about 20%), Aboriginal-owned land (about 20%) and 'other crown lands', mostly 'unallocated' lands not held for a defined purpose (19%) (Figure 36). Freehold lands that are more intensively developed for horticulture, forestry or urban areas remain sparse and cover less than 4% of remote Australia. There are also some large areas devoted to military training, but in total these represents less than 1% of the Outback.

These tenure figures are a little slippery, as categorisation varies across jurisdictions, there may be overlap among tenure categories and tenure doesn't necessarily reflect land use: for example, some pastoral leases are held by leaseholders (such as conservation organisations, Aboriginal groups, mining companies and individuals pursuing lifestyle living and recreation) who carry out little or no commercial pastoral activity. Some Aboriginal-owned land is also managed for conservation or for pastoral production. Furthermore, mining and gas exploration leases overlap most tenure types and extend across most of the Outback.

Existing tenure arrangements are in transition, with the current system regarded as a historic legacy that is constraining flexibility and is ill-suited to current and future challenges: for example, for northern Australia, but apposite for the entire Outback, a recent assessment concluded that:

' … the underlying complexity of tenures and entitlements on a given area of land; the capacity for investors to manage across multiple tenures and jurisdictions and resolve disputes efficiently; and the limits of some types of tenure to allow owners to leverage land assets for capital and development purposes, such as on some Indigenous tenures, are serious restrictions on further development' (Regional Australia Institute 2013).

Partly in response, government processes across most Outback jurisdictions are considering mechanisms to increase diversification options on some lands, particularly the pastoral estate. Furthermore, native title claims now encompass large parts of the Outback landscape, and their gradual resolution will bring some marked changes to Outback governance and land use.

The Outback is mostly administered through three tiers of government (federal, state/territory, and local) but the highly remote lands often

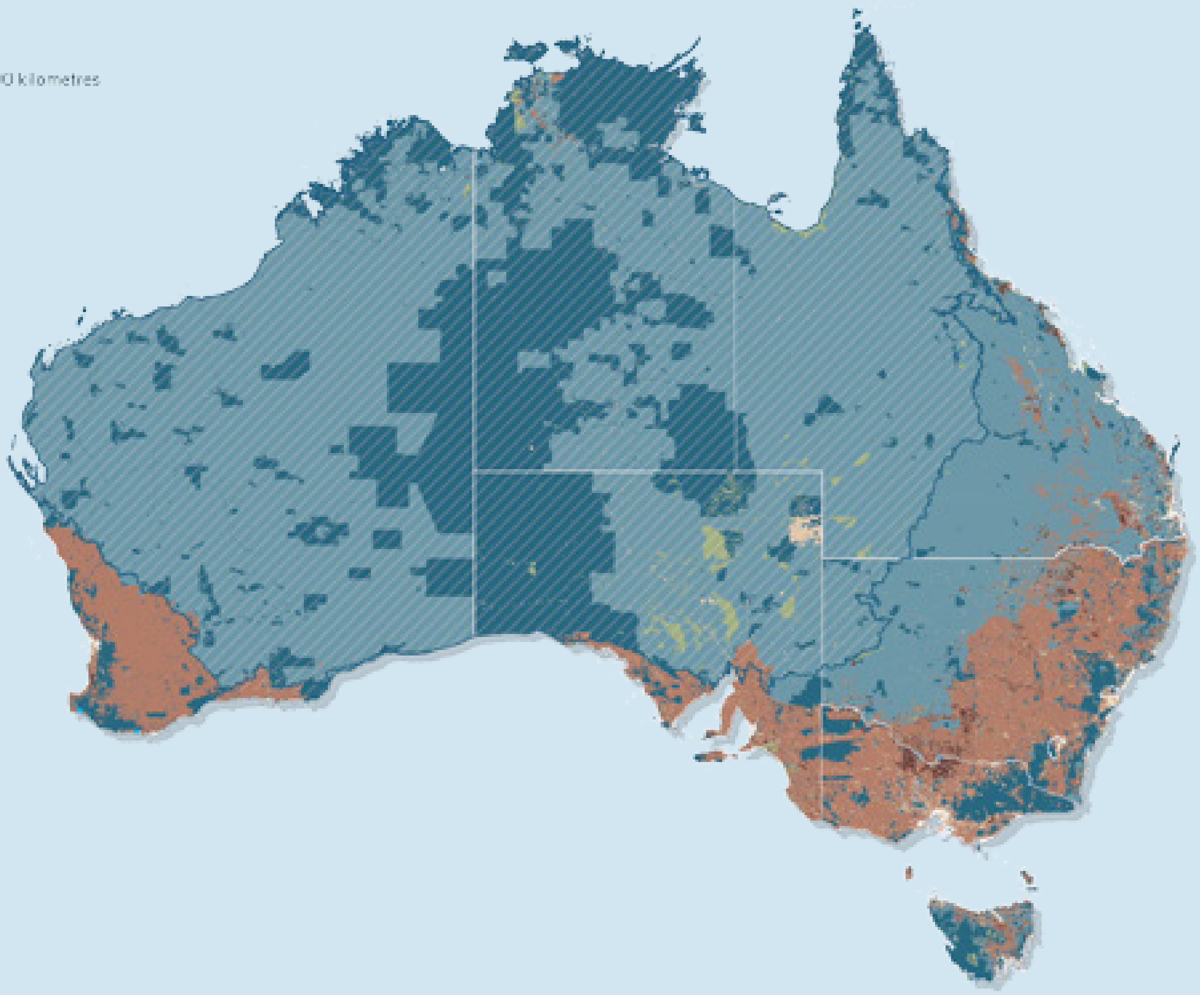
Pastoralism is the most extensive land use across the Outback, with states and territories issuing long-term leases over crown land. Beef cattle are the dominant livestock, with some areas also farming sheep and goats. These Braham cattle are on the floodplain of the Thomson River in Outback Queensland.

Figure 36

Broad Land Use and Tenure Across Australia

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: degree

0 250 500 kilometres



Primary land use

- Outback Australia
- Conservation and natural environments
- Production from relatively natural environments
- Intensive uses
- Production from dryland agriculture and plantations
- Productions from irrigated agriculture and plantations
- Lake beds

Source: Data from Australian Government Department of Agriculture

Figure design by The Pew Charitable Trusts

lack significant formal government infrastructure and have ad hoc and variably effective regional arrangements. Most national institutions and processes have been designed to serve coastal settled Australia, where more than 85% of the nation's people live, and these often fail in the sparsely populated Outback. A recent assessment of governance found that 'it is not clear who, if anyone, is setting the priorities for remote Australia and what those priorities are' and that current arrangements are not capable of resolving priorities or problems (Walker *et al.* 2012). As a general characterisation, Outback communities 'have little political power, little economic power and little financial power (except of course for the big mining companies, but their interests do not necessarily align with community interests)' (Fitzhardinge 2012).

To a substantial extent, the social and economic challenges of the Outback mirror those of its environmental traits and challenges. Many regional economies – particularly pastoralism and horticulture – fluctuate with climatic conditions. Many enterprises and regional economies are buffeted by boom–bust cycles, driven by largely unpredictable external factors, mostly relating to world commodity prices. Settlement and development patterns match the dispersion of environmental factors: human populations are small and scattered, but there are small, discrete areas of relatively high productivity.

For some characteristics, the social and economic challenges in the Outback are typical of remote areas worldwide. They are far from centres of power and hence their problems may be neglected or unappreciated. They are subject to external influences or attempted solutions, often imposed with little understanding of local conditions. Transport and other infrastructure are tenuous and distance renders the costs of living substantial. Institutional capacity is often meagre and opportunities for employment or enterprise limited.

Many communities in remote Australia have lamentable health, social and economic standards:

'Remote Australia exemplifies the conditions of a 'failed state', using four criteria developed by the Brookings Institute in 2006. These criteria are World Bank data that measure poverty, security issues relating to violence and homicide, the capacity of governments to provide basic needs for human development (particularly health and education), and the legitimacy of government in the lives of people' (Dillon and Westbury 2007).

6.3. Economy

Outback social and economic conditions are mixed (Figure 37). A recent assessment by the Regional Australia Institute concluded that there were markedly different economies and social states across remote Australia (Regional Australia Institute 2013). The few large regional cities (for the Outback only Darwin, but also a set of cities in coastal north-eastern Queensland just outside the Outback boundary used here) were likely to remain relatively prosperous and to grow, more or less regardless of the development approach taken by policy-makers. The economic condition and fate of mid-size towns were more uneven and insecure. Those placed near the northern cities have relatively secure logistical advantages. Mining towns have some of the strongest economic fundamentals of any region in Australia, but 'their wider competitive profiles are often poor, emphasising how much of the boom's growth has been driven by outside resources and has not translated into broader, sustainable, long-term competitive strengths for these regions' (Regional Australia Institute 2013). Other large towns associated with major intensive agriculture development (for example, Kununurra) and tourism hubs (such as Broome and Alice Springs) have reasonably well-established infrastructure, but may be somewhat vulnerable to external pressures, most notably to fluctuations in commodity prices and international markets. However, by far the largest part of the Outback – the remote pastoral areas and Indigenous communities – includes the least economically competitive regions in the nation and is marked by meagre infrastructure, limited institutional capacity, few economic prospects and dismal social and economic parameters. Planning for Outback futures must recognise these markedly different situations and opportunities.

> There is a history of boom-bust development in regional economies that parallels the boom–bust environments of much of the Outback.

There is another marked geographic influence on Outback economic potential. The northern Outback has some advantages over central Australia. It has higher primary productivity, so has more potential for carbon markets. Its coasts provide the basis for substantial recreational and fishing industries. It has more reliable and higher rainfall, so has more potential for some agricultural enterprises. And it is closer to the often-elusive markets of Asia, giving it a potential logistical advantage.

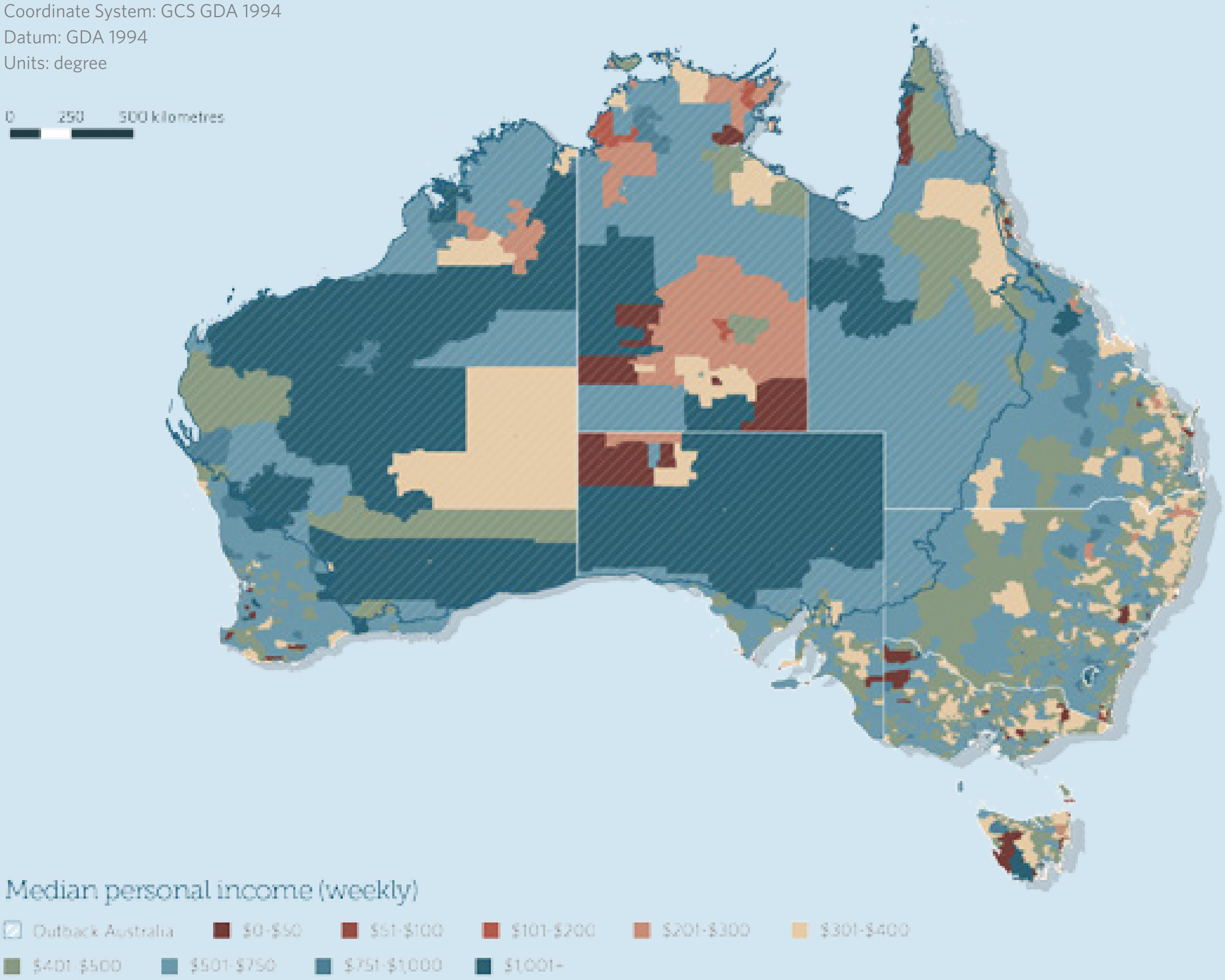
After government services, mining is the main economic power in the Outback. Exports of minerals and fuels amounted to A$135 billion in 2010 – by far the largest Australian export commodity. About 60% of current Australian mining operations, and more than 80% of developing mines, are in the Outback (Walker *et al.* 2012). Mining is focused on some key regions in the Outback, and these regions now present a marked contrast in economic indices to nearby Outback areas without such mining

Figure 37

Median Personal Weekly Income in Austtralia

Data reveal marked disparity across Outback areas

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: degree



Note: Some statistical divisions on which this map is based include very few people (<100) in the ABS database.

Source: Based on Australian Bureau of Statistics data

Figure design by The Pew Charitable Trusts

development (Figure 36). In the Outback, some of Australia's ostensibly most affluent areas abut some of its most destitute areas.

> Overall, there is a striking disparity in agricultural productivity between the Outback and the rest of Australia, with most Outback lands unprofitable.

In contrast, the 'profitability of the traditional industries of sheep and cattle, despite the short-term ups and downs, has been in steady decline for the last 30 years' (Fitzhardinge 2012). For much to most of the Outback pastoral industry – enterprises on infertile soils, remote from domestic markets, and reliant on volatile live-cattle export trade – 'the prognosis is at best economically marginal to unsustainable' (McCosker *et al.* 2010; Gleeson *et al*. 2012; Russell-Smith and Whitehead 2014). In many areas, the unprofitability or marginal profitability of enterprises has prompted landholders to attempt to increase short-term productivity by over-using marginal lands, leading to longer-term environmental decay and further entrenching longer-term unprofitability (Fitzhardinge 2012). Overall, there is a striking disparity in agricultural productivity between the Outback and the rest of Australia, with most Outback lands unprofitable (Figure 38) (Marinoni *et al.* 2012).

Most of the Outback's major commercial enterprises, even pastoralism, are geared for export outside Australia, and the narrow base renders these industries – and hence regional Outback economies – highly susceptible to market fluctuations. Consequently, there is a history of boom–bust development that parallels the boom–bust environments of much of the Outback (Stafford Smith 2008). Partly in response to such instability, there is an increasing desire from landholders and governments to seek more diversified land-use patterning (Puig *et al.* 2011; Fitzhardinge 2012).

Across much of the Outback, government service industries are the major employer. Tourism is a leading industry in some regions. Increasingly, there are also education, environment and health enterprises, with expertise marketed overseas.

A notable feature of the Outback is the disproportionately low level of investment in land-resource management relative to more settled parts of Australia. On a per-area basis, the investment by the Australian Government to non-Outback regions is typically at least 50 times more than for Outback regions (Robins and Dovers 2007).

Many Outback economies are compromised by a self-reinforcing pattern of high logistical costs, remoteness and scale:

'The tyranny of distance, and the paucity of skilled labour, results in a cost premium being realised for the development of infrastructure in remote areas. Project 'contingency' ... can be trebled when a project is located in more geographically remote areas. This is a direct function of the difficulty in attracting skilled labour, the cost of freight to move raw materials to a project site, accommodating workers, and a variety of other factors including the challenges of land tenure and leasing, or the lack of competition driving cost competitiveness ... the cost of essential services in remote areas are higher than for other parts of Australia. In smaller communities in particular, the lack of scale can prove to be a significant challenge in terms of attracting business interests' (Regional Australia Institute 2013).

6.4. Demography

A defining feature of the Outback is its sparse population. Across its nearly three-quarters of the Australian land area, the Outback supports about 800,000 people (less than 5% of Australia's population). Australia is now the most urbanised continent in the world and those urban areas are concentrated in coastal regions, particularly of eastern and southern Australia (Walker *et al.* 2012). Outside Darwin and the few major Outback towns, the average population density is less than 0.1 person/km^2 (Figure 39). This figure is extremely low relative to most of the rest of the world, for which the average population density is about 50 people/km^2.

There are very few large settlements in the Outback. The largest are Darwin (with about 120,000 people, including its satellite areas), Kalgoorlie–Boulder (36,000), Geraldton (29,000), Alice Springs (26,000), Mount Isa (26,000), Roebourne (22,000), Broken Hill (18,000), Port Hedland (16,000), Broome (16,000), Karratha (12,000) and Katherine (10,000).

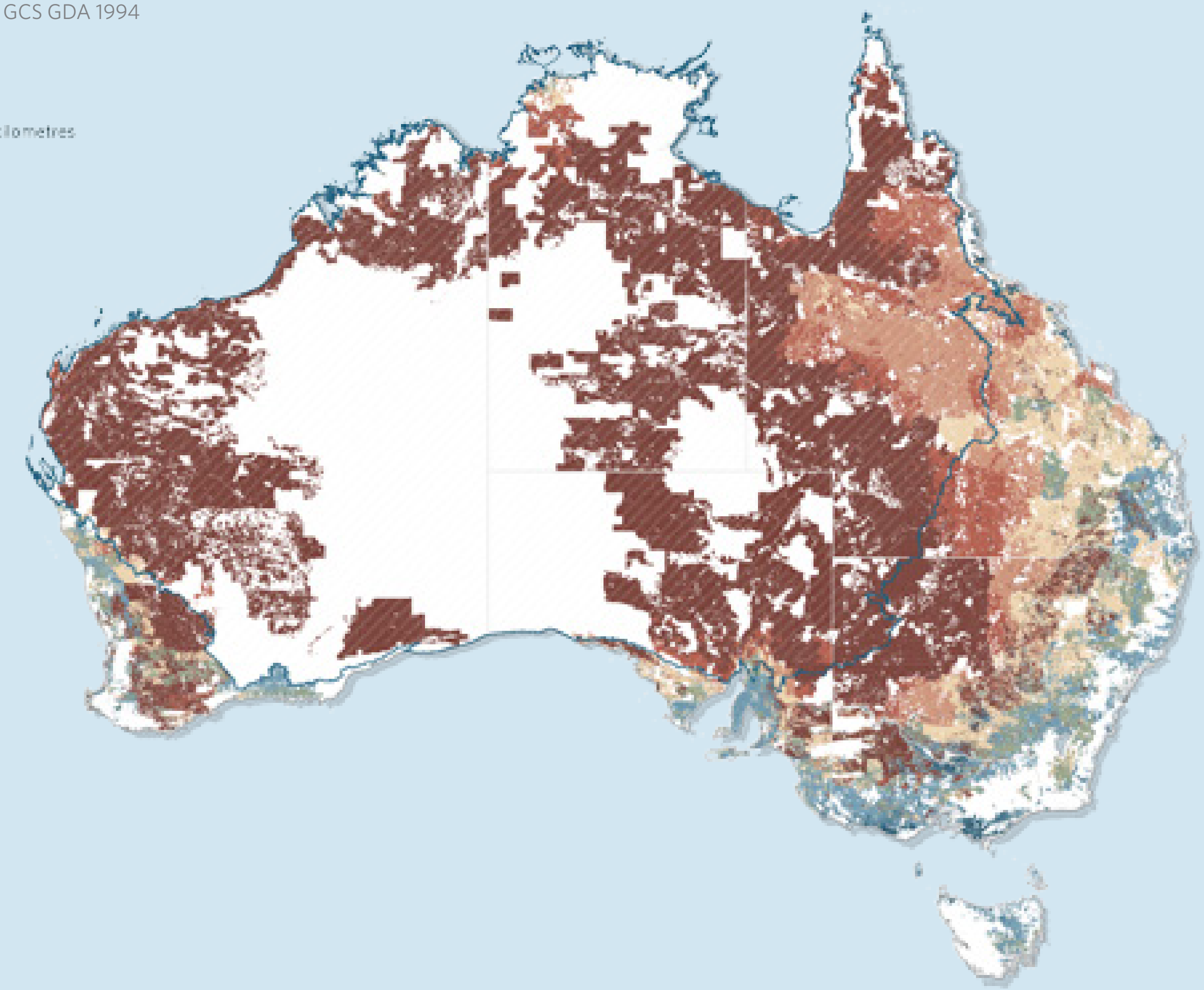
Aboriginal people make up about 25% of the total Outback population, with that proportion increasing to about 45% in areas classified by the Australian Bureau of Statistics as very remote (Taylor 2006; Biddle and Yap 2010). This proportion varies significantly across Outback areas (Figure 40). In the Northern Territory, 70% of the non-urban population is Indigenous, almost all residing in small dispersed communities. There are about 1200 such communities across the Outback, of which 1000 have a population of fewer than 100 people (Altman *et al.* 2007).

Figure 38

Profit at Full Equity for Australia, 2005–06

Values are in Australian dollars per hectare

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: degree



Source: Reprinted from Marinoni et al. (2012). Copyright, with permission from, Elsevier

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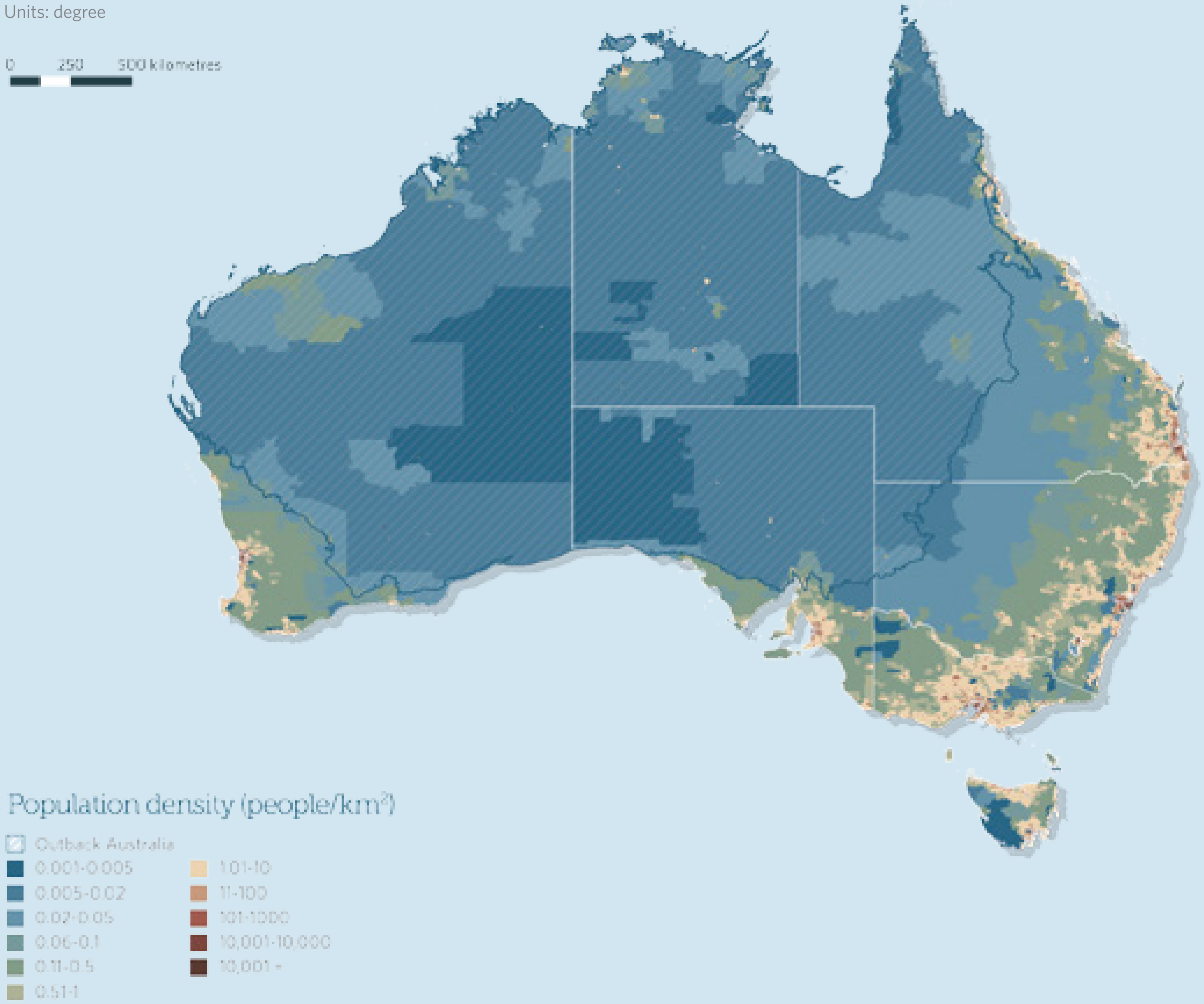
Figure 39

Population Density Across Australia

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: degree

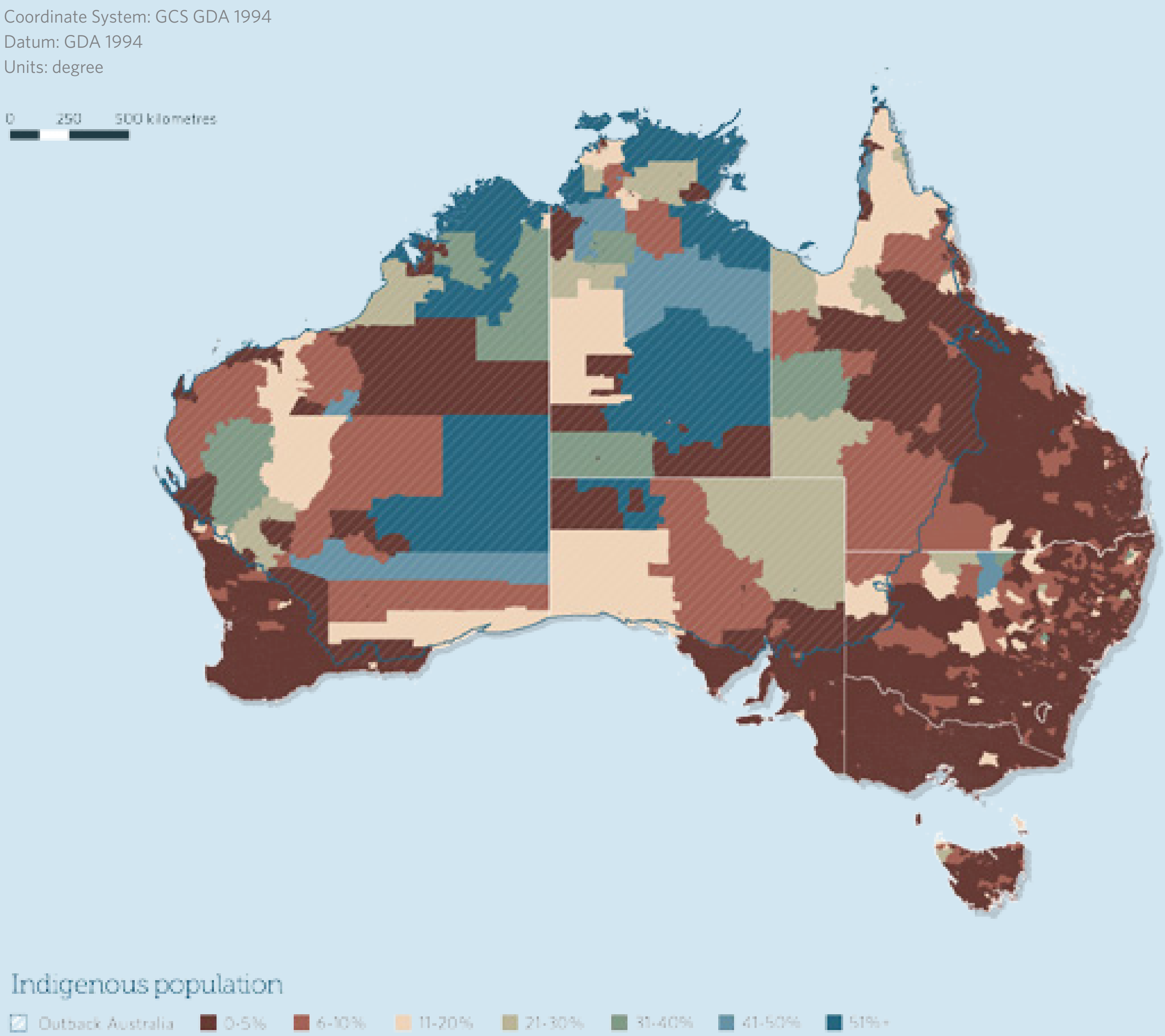


Source: From Australian Bureau of Statistics

Figure design by The Pew Charitable Trusts

Figure 40

Spatial Variation in the Percentage of the Overall Population That Is Aboriginal



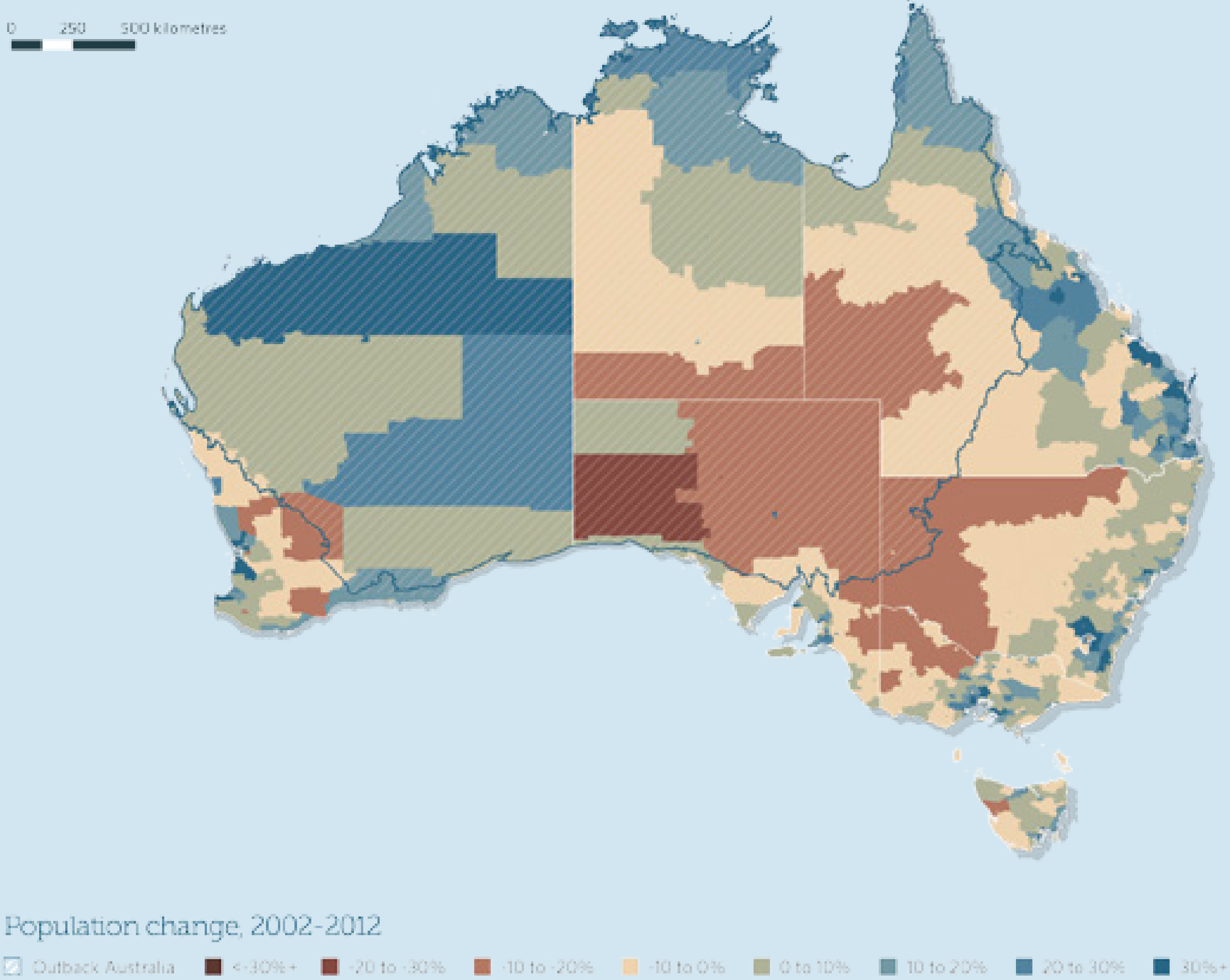
Source: From Australian Bureau of Statistics

Figure design by The Pew Charitable Trusts

Figure 41

Population Change in Australia, 2007–12

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: degree



Source: From Australian Bureau of Statistics

Figure design by The Pew Charitable Trusts

The Outback town of Thargomindah lies in south-west Queensland, 1,100 kms west of the state capital, Brisbane. Thargomindah, which has a population of about 230 people, is named from the Aboriginal word for 'Cloud of Dust'.

There are markedly different population trajectories across Outback areas. Some regions, notably those including some of the major towns and dynamic mining areas are experiencing population growth. Other regions are stagnating or suffering population decline. In contrast to much of the period since European settlement, proportional population growth rates in many Outback areas now outstrip those of the more densely settled areas (Figure 41), partly due to the relatively high birth rates – and, from a low base, increasing survival rates – in many Aboriginal communities, and partly due to massive mining developments in some Outback regions. This relative growth represents both a challenge – because much Outback infrastructure struggles already to support the limited population – and an opportunity, as the Outback moves from a backwater to an increasingly pivotal role in the nation's economy. Population growth rates are appreciably higher in the Indigenous than non-Indigenous population (Brown *et al.* 2008). For example, growth rates over a 15-year period were predicted to be 26% in the Outback Indigenous population but only 15% for the non-Indigenous population (Taylor 2006). One consequence is that numerous Outback towns that were established to service the mining and pastoral industries are now becoming predominantly Indigenous welfare-dependent settlements (Walker 2012).

6.5. Human interactions with Outback landscapes

This intrinsic and indivisible connection between the land and its people is fundamental to Indigenous culture and aspirations, and a key responsibility for Indigenous landowners is to care for their country. A series of recent studies has corroborated the tenet, demonstrating that key Indigenous health and other socio-economic indicators are better at Outback sites at which functional ranger groups are taking responsibility for the care and maintenance of their lands, most notably through the management of fire (see Spotlight 8).

> This intrinsic and indivisible connection between the land and its people is fundamental to Indigenous culture and aspirations, and a key responsibility for Indigenous landowners is to care for their country.

Annabelle Sandes

Although there are few large towns in the Outback, there are many small, often very isolated, Aboriginal communities. Mowanjum Aboriginal Community (pictured) in Western Australia benefits from being close to the regional centre of Derby. Mowanjum was established as a Presbyterian mission in the late 1800s and now supports a strong community of Indigenous artists.

Spotlight 8 **The many benefits of managing country**

Outback landscapes that are empty of people experience more pronounced environmental degradation than comparable landscapes subject to traditional Aboriginal management (Bowman *et al.* 2001; Yibarbuk *et al*. 2001; Burrows *et al.* 2006; Russell-Smith *et al*. 2009b). The benefits relate particularly to fire-sensitive species and ecological communities, and to species that are advantaged by a finer-scale patchwork of environments. The environmental benefits also arise from the moderation of greenhouse gas emissions with more controlled fire regimes (Edwards *et al* 2008).

> Across Outback Australia, the land benefits from being managed by people, and people benefit from managing the land.

Over the past one to two decades, the implementation of a series of policy initiatives – including the Indigenous Protected Area program and payments for environmental services through Caring for Country and Working on Country ranger groups – has provided institutional support for Aboriginal land management across extensive areas of the Outback. Indigenous Protected Areas are sites on Aboriginal-owned lands subject to a non-binding agreement between traditional owners and the Commonwealth relating to management activities and objectives for conservation and other activities.

Currently, Australian and state governments provide funding for more than 700 ranger positions. Many Indigenous ranger programs are now major service providers for a wide range of environmental activities on conservation reserves, in mining areas and across broader landscapes. For Indigenous residents, land and sea management activities provide a variety of environmental services including:

- biodiversity conservation survey and monitoring;
- cultural site maintenance – including survey and monitoring activities;
- feral animal and weed management – including survey and monitoring activities;
- landscape-scale fire management, including 'savanna burning' for greenhouse gas emissions abatement;
- carbon sequestration projects;
- protected lands management and associated tourism opportunities;
- arts and crafts celebrating connections with lands and seas;
- sustainable commercial harvest of native plants and animals;
- participation in research for natural resource management; and
- other contracting services – e.g. quarantine, customs, fencing, road maintenance (Ferguson 2012; Russell-Smith and Whitehead 2014).

Increasingly, there has also been recognition that Indigenous land (and sea) management could help build individual and institutional capacity in remote communities, and that it also delivered a wide range of other collateral benefits, including improved health, employment and educational standards, revitalisation of culture and pride, the development of mature regional partnerships with other groups, and substantial economic opportunities (Burgess *et al.* 2005; Davies *et al.* 2008; Altman *et al.* 2011; Altman and Kerins 2012).

A recent review of the Indigenous Protected Area program found that:

- 95% of IPA communities reported economic participation and development benefits from involvement with the program;
- 60% of IPA communities reported positive outcomes for early childhood development from their IPA activities;
- 85% of IPA communities reported that IPA activities improve early school engagement;
- 74% of IPA communities reported that their IPA management activities make a positive contribution to the reduction of substance abuse; and
- 74% of IPA communities reported that their participation in IPA work contributes to more functional families by restoring relationships and reinforcing family and community structures (Gilligan 2006).

Indigenous people living on country and engaged in hunting, fire management and other environmental activities are more likely to maintain strong culture (notably including the maintenance of Aboriginal languages) (Australian Institute of Aboriginal and Torres Strait Islander Studies 2005; Gorenflo *et al*. 2012), more likely to participate productively in an alternative economy (Altman 1987; Altman and Whitehead 2003), and more likely to be healthy (Burgess *et al*. 2005; Burgess *et al.* 2009; Garnett *et al.* 2009; Berry *et al*. 2010; Campbell *et al*. 2011).

At left, rangers Jarvis Fernandez, Jamie Brown and Steven Kopp of the Paruku Indigenous Protected Area erect a conservation area fence on the edge of the Great Sandy Desert. At right, Nanum Wungthim Land & Sea Ranger, Angela Christie, holds a turtle egg from the coastline of western Cape York. The rangers, from Napranum near Weipa, provide natural resource management for stretches of coastline, rivers and lagoons, as well as inland areas. The rangers learn turtle management as part of their training.

A Ngurrara Ranger transfers knowledge about managing the land to a young community member at the Warlu Jilajaa Jumu Indigenous Protected Area in Western Australia's Great Sandy Desert. Rangers have become positive role models in their communities, with many Aboriginal children aspiring to become rangers when they leave school.

In one study conducted over seven years in central Australia, a series of health indicators (including incidence of diabetes, hypertension, obesity, hospitalisation, mortality, injury) was compared between Aboriginal people living in homelands (remote outstations) relative to those living in more centralised communities (McDermott *et al*. 1998). Aboriginal people living on remote communities consistently had better health outcomes than the matched sample in larger communities: for example, mean age at death was 58 in the homeland cohort and 48 for Aboriginal people in larger communities. This health benefit from living on country is a notable outcome itself, especially given the parlous state of Indigenous health generally; but it also provides a substantial economic benefit. A subsequent analysis (Campbell *et al.* 2011) calculated that, for a nominal community of about 1200 Aboriginal people, the annual cost savings derived from outstation living, in terms of health expenses avoided, is about A$160,000 to A$270,000 (for diabetes and hypertension alone). Scaled up over other health parameters and far more broadly across the Outback, these represent significant economic benefits.

Comparable research in Arnhem Land (the Health Country Healthy Living study) has examined health (physical and mental) and social and economic characteristics of a stratified sample of Aboriginal people involved (to different degrees) or not involved in land management and ranger programs, and reported on Aboriginal perceptions (Johnston *et al.* 2007). The study concluded that:

'Aboriginal peoples maintain a strong belief that continued association with and caring for ancestral lands is a key determinant of health. Individual engagement with 'country' provides opportunities for physical activity and improved diet as well as boosting individual autonomy and self-esteem. Internationally, such culturally congruent health promotion activities have been successful in programs targeting substance abuse and chronic diseases' (Burgess *et al*. 2005).

The analytical studies backed up these perceptions. With a range of demographic factors carefully controlled, an increased participation in ranger activities was found to result in significantly better outcomes for all health measures assessed, including body mass index, obesity, blood pressure, diabetes, cholesterol levels, haemoglobin levels, cardio-vascular disease and stress (Burgess *et al.* 2009). It also demonstrated substantial benefits for mental wellbeing (Berry *et al.* 2010). Considering only a small subset of the health issues (hypertension, diabetes and renal disease), the annual savings in primary health care for the study population of about 1200 Aboriginal people was estimated at A$270,000 (Campbell 2011; Campbell *et al.* 2011). The two examples from two small areas of central and northern Australia, indicating substantial direct economic savings to the health budget from even these small samples suggest that the investment made by government in Indigenous Protected Areas of about A$180 million over five years across Australia (Campbell 2011), is likely to provide a substantial net economic benefit in addition to its environmental and social outcomes.

> These health and social benefits arising from Indigenous land management activity directly address chronic and severe Aboriginal disadvantage and offer hope towards a solution that has evaded decades of policy initiatives and investment.

Land management and ranger work also provide key employment opportunities in regions in which few other options are available. It provides scope for education and training, for protection and maintenance of cultural assets, for inter-generational transfer of culture and for broader recognition of traditional land-management expertise. It provides pride and purpose.

These health and social benefits arising from Indigenous land management activity are not trifling and peripheral. They directly address chronic and severe Aboriginal disadvantage and offer hope towards a solution that has evaded decades of policy initiatives and investment (Garnett *et al.* 2009).

The IPA and Indigenous ranger programs have developed rapidly and have demonstrated some major successes. However their funding base remains constrained and largely short-term. Long-term security for support for these programs is a vital component of planning for social, economic and environmental sustainability for the Outback's future.

Martu rangers repair a track in the Birriliburu Indigenous Protected Area, Gibson Desert, Western Australia. The IPA is home to a large number of threatened species.

While the interconnection between people and natural environments may be ingrained and existential for Aboriginal people in the Outback, there is a strong and increasingly realised tie with the land for all Outback residents – a sense of belonging and a recognition that people's existence and future in the Outback is contingent on its nature and our dealings with it. In a recent review of the historic development and future of the Outback, the pastoralist Guy Fitzhardinge emphasised the interdependent links between Outback people and environments:

'The rangelands of Australia and their communities can be represented as a diverse and interrelated complex of social and ecological systems. (These) … exist in a complementary alliance that supports a sustainable future for both. I choose the words 'complementary alliance' carefully, as they underpin another significant and related shift in thinking. The settlement of the rangelands has been a history of exploitation. The value of the rangelands was seen in agriculture and its 'use' as a factor of production in such enterprises as wool and red meat. The landscape was valued solely in these terms. Further, the degradation of landscape value (even in these terms alone) was seen as justifiable in the context of being a factor of production. However, this assumption is no longer the case as wider community attitudes have changed. … There is a growing recognition of the other landscape elements that are of value to the local and wider community and, importantly, many of these elements are crucial in supporting rangelands communities themselves. The ideal that healthy ecosystems are fundamental to healthy social systems is now generally accepted' (Fitzhardinge 2012).

There is something special about this connection. For the arid Outback, but probably largely pervasive across all Outback areas, CSIRO scientist Mark Stafford Smith considered that there is a 'desert syndrome' (Stafford Smith 2008), an inter-mixed set of environmental and social features that are not individually unique but which together cause it to function in ways that are fundamentally different to other physical and social environments. He concluded that appreciation of these factors (and their interrelationships) was a necessary precondition for the successful design and application of any policy, planning or management initiative for the Outback. These factors and their interrelationships are presented in Figure 42.

The syndrome was conceptualised for the Australian deserts, but is applicable more generally across the Outback. The main differences are in the underlying physical factors: relative to the arid Outback, monsoonal northern Australia has a climate that is more predictable and has higher rainfall, and productivity is somewhat higher. Consequently, the monsoonal Outback has a higher population and density of settlements.

The bonds between human life in the Outback and its natural environments and ecological processes are pervasive. At one extreme are Aboriginal communities living largely traditional lives in remote outstations, dependent in large part for food and other resources from the natural environment and with explicit and important responsibilities for maintaining the condition of their clan estates (Vardon *et al.* 1999). At another extreme are large mining ventures that may still depend on and be linked to the natural landscape for the provision of water and the viability of their rehabilitation. These industries also are influenced by the physical and social factors of remoteness, generally limited infrastructure and capricious weather.

> In the Outback, human life and ventures depend on the natural environment and its wellbeing.

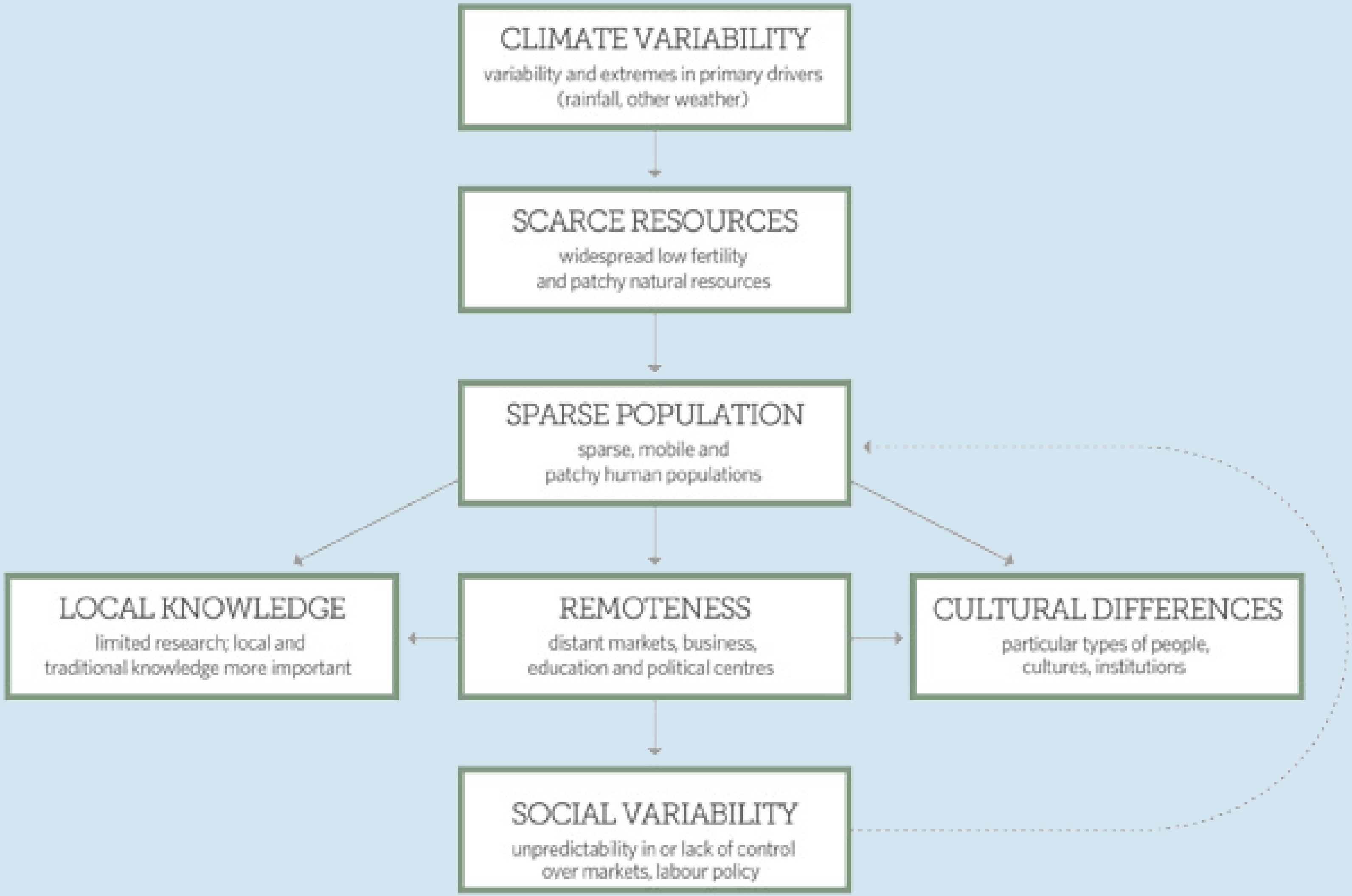
Almost all pastoral activity still depends on native vegetation – although with varying levels of transformation of native to introduced grasses – and natural water sources. Tourism focuses almost exclusively on natural environments, particularly at specific and spectacular localised features, but also on the more general flavour of the vast 'wild' Outback experience. Recreational and commercial fishing depends almost entirely on native species and the maintenance of hydrological function and landscape condition. The commercial wildlife harvest and 'bush tucker' industries largely depend on collecting produce from native species in well-managed natural environments. Even the pockets of intensive horticulture in the Outback largely depend on functioning hydrological systems and may be supported in part by neighbouring intact bushland environments that provide habitat for native predators that help control some pest species.

Freshly collected 'bush tucker' – water lily bulbs – gleaned from an Outback waterhole on Cape York Peninsula, Queensland.

Figure 42

The 'Desert Syndrome'

Interrelated landscape and social factors need to be considered in policy, planning and management initiatives



Source: Stafford Smith (2008)

Figure design by The Pew Charitable Trusts

Tourists explore Yellow Water Billabong at the end of Jim Jim Creek, one of the wetland highlights of Kakadu National Park in the Top End, Northern Territory. Kakadu is home to more than one-third of Australia's bird species and one-quarter of its freshwater and estuarine fish species.

Recreational fishermen try their luck in the Top End. Northern Australia is a popular sport and recreational fishing destination, with the prolific Barramundi being one of the most prized fish to catch and eat.

In the Outback, human life and ventures depend on the natural environment and its wellbeing. To a large extent, nature provides the green infrastructure on which all Outback activity and enterprises are based, and the likelihood of long-term viability in these activities and enterprises relies on maintaining the strength and integrity of this infrastructure.

And the relationship is bilateral. The condition of many Outback environments and ecological processes is affected by human activity. Again, this is manifest across a spectrum of inputs, with the most comprehensive inputs occurring in remote Aboriginal outstations at which traditional fire management is practised intensively and assiduously, to the benefit of many native plant and animal species. But across almost all land users and tenures, Outback residents are also involved in some pest and weed control and there is increasing recognition – voluntarily or by regulation – of the benefit and obligation to maintain or enhance the condition of natural water sources. In parts of the landscape without human populations, or without active environmental management, biodiversity and other landscape values can decline as fire regimes become uncontrolled and detrimental, and weed and pest species increase, causing degradation to significant areas (Bowman *et al*. 2001).

> To a large extent, nature provides the green infrastructure on which all Outback activity and enterprises are based, and the likelihood of long-term viability relies on maintaining the strength and integrity of this infrastructure.

Furthermore, and extending the 'desert syndrome' characterisation, many of the factors that define and underpin the pattern and health of biodiversity in the Outback are also of significant consequence for humans and their systems. So, the scarce and patchy productive resources of the Outback are linchpins not only of its ecology but also of its land use potential and impacts. The marked seasonal contrasts of monsoonal northern Australia and the decadal-scale unpredictable rainfall fluctuations of arid Australia underpin not only the ecological function and biodiversity patterning of these areas, but also constrain and channel land use and its impacts. Water is a key and often limiting resource for ecological functioning and biodiversity, and also for land use and its impacts. Fire, in different manifestations, is a major driver (for advantage and disadvantage) of Outback ecology and also affects, and is affected by, land use and its impacts. In the Outback, the 'forces of nature' not only control and belong to that nature – they also shape patterns of human life and settlement.

6.6. The Outback as icon: myth and symbolism in Australian culture

All Australian lands and waters, and the life within them, have (or at least had) some significance to Aboriginal culture. These associations may be particularly profound in the Outback. Across the Outback, many Aboriginal communities have retained pivotal cultural connections with land and spiritual responsibilities to look after it. Across much of these lands, knowledge of the location of water sources and fertile areas was instrumental for survival and moving about the landscape required 'seeing' features in a near featureless landscape – of finding pathways in a trackless space. In a low productivity environment, it is critical to know the land and its capability and to work the landscape intimately, assiduously and expertly to draw and sustain resources and to finesse the landscape to favour particular plants and animals. To survive in the Outback, human societies must know, respect and care for it and honour the lessons handed down over generations. This intimate knowledge, symbolism and interrelationship are expressed in Aboriginal lore and art. It is the meaning within dot paintings from central Australia, the juxtaposition of objects within bark paintings from Arnhem Land, the stories expressed in rock art in the Kimberley, the symbolism in petroglyphs in the Burrup Peninsula and the essence of dance and ceremony. It is a description and an interpretation of the Outback landscape – the indivisible place of humans in it, and the connections entrenched over countless generations – of the place nurturing the people and the people nurturing the place.

> For Aboriginal people, the Outback was and is a familiar, comforting, bountiful landscape. For the first Europeans in the Outback, it was often strange, hostile and barren.

This culture is most resilient in the remote Outback, and in part that remoteness has served to conserve and maintain culture. One example is in the status of Indigenous languages, which have remained appreciably stronger and more widely used in more remote Outback areas (Figure 43).

For Aboriginal people, the Outback was and is a familiar, comforting, bountiful landscape. For the first Europeans in the Outback, it was often strange, hostile and barren – the Outback claimed many. A perception of the Outback as an unwelcoming and harsh land has been etched deeply into the Australian psyche since the hard lesson of 19th century explorers Robert Burke and William Wills' ill-fated search for bounty in the Australian interior. But it is also an arena of triumph, of battles hard fought and won. Tourism Australia (2009) celebrates this theme: 'Australia's Outback history from 1880 onwards is a saga of exploration and development, demonstrating the triumph of a pioneering spirit' (http://www.tourism.australia.com/story-ideas/the-outback-1761.aspx). Indeed, the resilience and character of its peoples are key parts of the tradition, strength and feel of the Outback. In a remote and challenging land, it pays to be independent, self-sufficient and resourceful, and for people in small communities to look after each other, to try to live within their means and to safeguard the future.

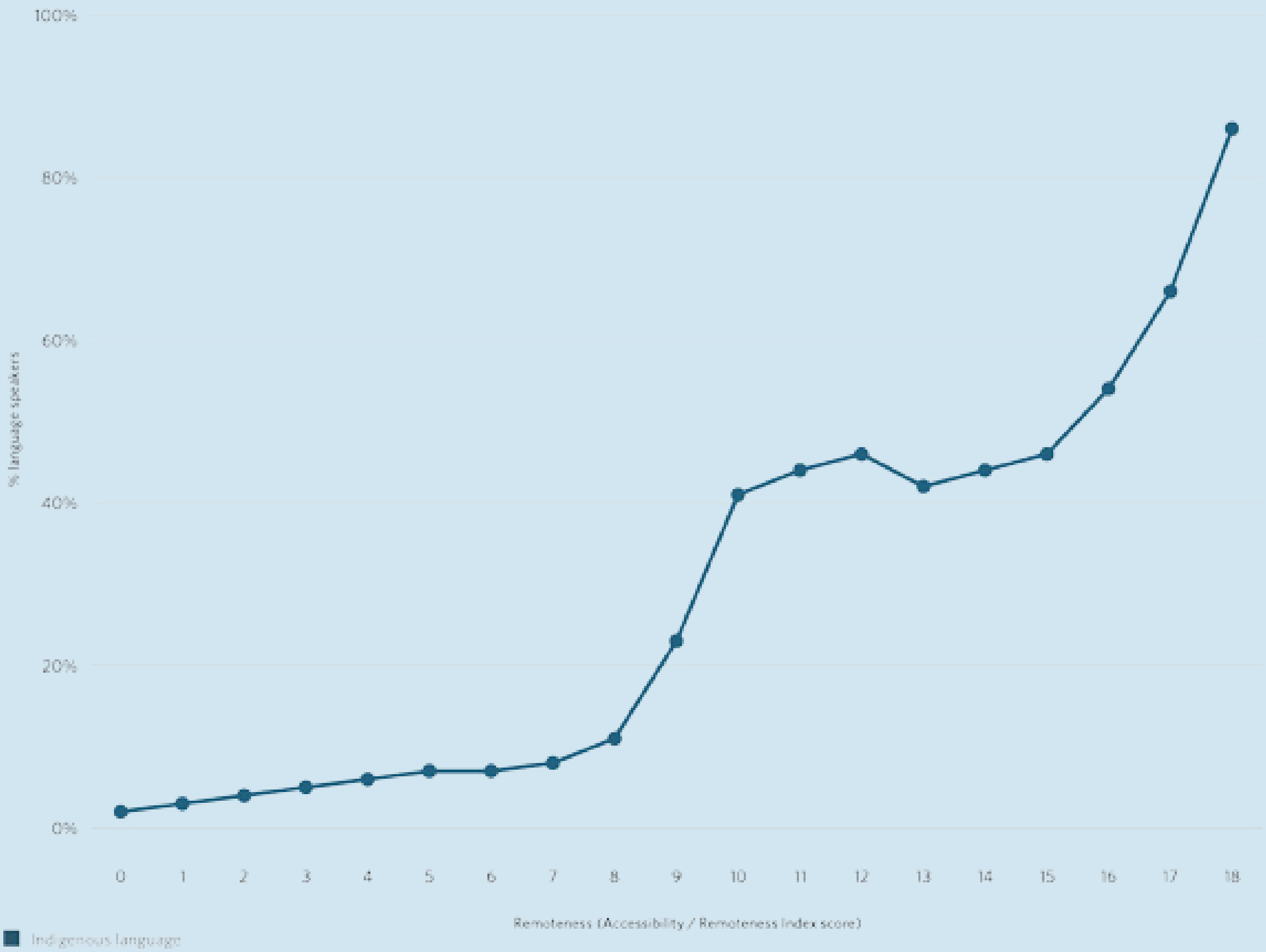
Almost all Australians have a fascination for the Outback – a recognition that the heart, core and grandeur of the nation lies in the Outback and that it defines the country and what it is to be Australian. Perversely, for most Australians, it is an alien landscape, but also one into which we're born. We know we belong in this landscape, but it is mostly a hard place and gives its bounty sparingly. It is a land with unnerving spiritual power branded from antiquity. Australian perceptions of the Outback focus particularly on the core icons of Kakadu and Uluru, but also on the landscape between as providing either a boundless sense of space or monotonous emptiness.

The Outback figures large as a focus, context and character in Australian art, film and literature. Among the defining classics, it is the dread forge that shapes the destiny and character of the protagonist in Patrick White's quintessential Australian novel, *Voss*. It is the desolation and menace in the films *Mad Max, Wolf Creek* and *The Rovers,* but also the comforting wonder-filled home in *Jedda* – or both of these extremes, as in *Crocodile Dundee*. It is the landscape paeans, of nature far larger than humans, in the paintings of Fred Williams, Russell Drysdale or Pro Hart. It is the heart, meaning and mystique in the dot paintings of Emily Kame Kngwarreye and Clifford Possum Tjapaltjarri and the powerful landscapes of Rover Thomas. It is the spirit in the national anthem ('Our land abounds in Nature's gifts, of beauty rich and rare'), and it is the enduring character in Dorothea Mackellar's *My Country* – the closest thing we have to a national poem. It is the epic and the context that helped define Australians in the rollicking yarns and poems of Banjo Patterson and Henry Lawson, and it is the evocative and stirring centrality of place in such anthemic popular Australian songs as *Great Southern Land, Solid Rock Sacred Ground* and *My Island Home* and equally, but differently, in the symphonies of Peter Sculthorpe.

> Almost all Australians have a fascination for the Outback – a recognition that the heart, core and grandeur of the nation lies in the Outback and that it defines the country and what it is to be Australian.

Figure 43

Prevalence of Aboriginal Language in Western Australia by Degree of Remoteness



Source: Australian Institute of Aboriginal and Torres Strait Islander Studies (2005)

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Figure design by The Pew Charitable Trusts

The Outback affords visitors the opportunity to head off the beaten track and immerse themselves in a true, and increasingly rare, wilderness experience.

> The threats facing remote Australia, and its global importance, are not front-of-mind for the great majority of Australians.

To some extent, this cultural referencing establishes a set of iconic images of the Outback that resonates strongly for most Australians and serves as the drawcard for most international tourists. There is a thirst for this 'Outback experience' among much of the Australian population, for whom the great four-wheel-drive Outback adventure is a rite of passage, a celebration of national history, culture and environment, a quest for identity and a must-do trek in retirement. But generally and more prosaically, the Outback, its ecology, its peoples and their lifestyles and economies all remain relatively little known by most Australians. Fewer than 5% of Australians live in the Outback, and even fewer share the responsibility of managing the millions of square kilometres of country. The threats facing remote Australia, and its global importance, are not front-of-mind for the great majority of Australians. Distance makes them hidden from easy view and analysis and this lack of knowledge and understanding is hindering positive change.

The Outback also provides a meeting ground, a national opportunity for reconciliation. It is a place in which Indigenous Australians are more at home than most Australians of European origins – a place in which they also have a growing level of explicit and recognised ownership and responsibility. It is a place in which Indigenous culture may still shine brightly and where Australians of European origins can learn from and respect traditional knowledge and more readily tap into the deeper roots of our land. It is a place that may allow for the development of a more complex, nuanced and substantial national identity, and of a renaissance of Indigenous culture.


Glenn Walker

A modern-day 'swagman' settles in for the night on the banks of Combo Waterhole, a billabong on the Diamantina River, Queensland. This site inspired Banjo Paterson, one of Australia's most important poets, to write the lyrics for "Waltzing Matilda," the country's unofficial anthem, in 1895.

Four-wheel driving through the Outback is a 'rite of passage' for many Australians. This group is travelling through the Simpson Desert during the stunning wildflower season.

Many invasive pest animals cause significant damage to the nature of the Outback. Cane toads were introduced from central America in an attempt to control pests in sugar cane crops. However, they poison many native predators, such as quolls and goannas, which eat them.

7. Devaluing the Outback – threats and concerns

In previous sections we have argued that the Outback is special and that collectively its environments are of outstanding international value. Here, we note that the Outback also has problems. We describe these problems not to resile from or dilute our previous recognition of the Outback's international value, but because these problems demonstrate that there are weak points in the functioning of the Outback and that we should not take for granted that its values will be maintained. Much needs to be done to achieve such an objective.

7.1. Evidence of declining biodiversity values

Even in Outback areas remote from signs of humans, some native plant and animal species are in decline and some have disappeared irrevocably. In many areas, the thin lens of relative soil fertility has been spent and the land's potential productivity diminished. Across extensive areas, the intricate pattern and process of traditional fire management has been lost or withdrawn, and instead the land now burns extensively and without purpose or finesse.

Recognition of the susceptibility of the Outback's native plants and animals to ostensibly minor changes is not new. About 70 years ago, witnessing the initial unravelling of components of the Outback's fauna, one of the most perceptive observers of Outback ecology, Hedley Finlayson, lamented those losses and proposed the causes in his book *The Red Centre: Man and Beast in the Heart of Australia* (Finlayson 1945) (see Insight 6). Sadly, much that he predicted has happened, and his solution, of a large network of Outback reserves in which threats are controlled, has not yet been realised.

Insight 6

Remote and natural is not necessarily enough

The Outback is remote, largely natural and apparently little modified. It is not unreasonable to consider that these qualities proffer an exceptional conservation security for the Outback's biodiversity. But this is not the case. The Outback is beset by many factors that we barely notice, but these factors have served to subvert at least parts of its biodiversity even in areas that otherwise appear largely pristine. It is a reckoning noted at least 50 years ago, by one of the most perceptive of the Outback's early naturalists, Hedley Finlayson:

'True, much of the settlement so effected is very sparse so far as the human element is concerned, and incredulity is often expressed that such occupation as obtains in many parts of the interior could have caused appreciable changes to the original conditions. It is not so much, however, that species are exterminated by the introduction of stock – though this has happened often enough – but the complex equilibrium which governs long established floras and faunas is drastically disturbed or even demolished altogether. Some forms are favoured at the expense of others; habits are altered; distribution is modified, and much evidence of the past history of life of the country slips suddenly into obscurity.

The old Australia is passing. The environment which moulded the most remarkable fauna in the world is beset on all sides by influences which are reducing it to a medley of semi-artificial environments, in which the original plan is lost and the final outcome of which no man may predict.

The man in the street has heard and read so much of a vast, empty centre that the conception of an untrodden wilderness enduring for all time has taken root ... But it must always be remembered that even in those tracts where no stock have been depastured, those enterprising pests, the rabbits, foxes, and feral cats, have in many cases gone on before and worked untold change and damage' (Finlayson 1945).

Mostly, our society hasn't appreciated Finlayson's perception and warning. Left unmanaged, the distinctive life of the Outback will continue to fade away.

The environmental losses have been most evident, or at least best documented, for the Outback's diverse and distinctive native mammal fauna. Across much of inland Australia, a high proportion (in some regions, more than half) of the original number of mammal species has been lost. Many of these hung on until their final disappearance in the 1950s and 1960s. The most recent review lists the recently extinct mammal species of the Outback as Pig-footed Bandicoot, Desert Bandicoot, Lesser Bilby, Desert Bettong, Nullarbor Dwarf Bettong, Desert Rat-kangaroo, Broad-faced Potoroo, Central Hare-wallaby, Crescent Nailtail Wallaby, Lesser Stick-nest Rat, Short-tailed Hopping-mouse, Long-tailed Hopping-mouse, Broad-cheeked Hopping-mouse and Gould's Mouse (Woinarski *et al.* 2014). Many other species disappeared across their previously vast Outback range, but fortuitously survived on offshore islands or in intensively managed areas in small remnants of their former range, affording them a rare second chance.

Many additional Outback mammals are facing the same bleak outlook, now declining across most of their range. In particular, there is now a spate of declines among mammals of northern Australia, an area previously considered to be relatively untouched by biodiversity loss (Woinarski *et al.* 2010; Woinarski *et al*. 2011a) (Table 4).

This table shows results from two monitoring studies in Kakadu National Park. The first was restricted to the Kapalga region of the Park and compared trap success rate in the same sites in 1985–87 and in 1999 (Woinarski *et al.* 2001). The second study occurred more extensively across Kakadu, and this table reports change in abundance from a 2001–04 baseline to a re-sampling of the same sites in 2007–09 (Woinarski *et al*. 2010). Not all species are reported in this table.

Table 4

Decline in Mammals in Northern Australia

Species	Kapalga study		Kakadu study	
	1985–87	1999	2001–04	2007–09
Fawn Antechinus	8.3	0	0.40	0.04
Northern Quoll	1.4	0.03	0.49	0.02
Northern Brown Bandicoot	2.5	0.07	0.34	0.04
Common Brush-tailed Possum	0.5	0	0.07	0.01
Black-footed Tree-rat	0.33	0	0.01	0
Pale Field-rat	7.8	0	0.70	0.04
All species	23.7	3.3	4.7	1.2

Table design by The Pew Charitable Trusts

> We should now be more aware of the likelihood of further loss and of a responsibility to attempt to avoid it, by managing these lands in a proactive and competent manner.

The losses of Outback mammals are not a simple, transient and now historic red entry in the national accounts book. These mammals included some of the most distinctive and interesting species in the world. Many had deep-rooted cultural significance, as totems, ancestor figures and food in Indigenous culture. And many were not passive parts of Outback ecology, but played important functional roles in those ecosystems. Their loss represents a fraying of the distinctive fabric of the Outback environment – a weakening of what makes the Outback such a special place. These losses occurred at a time of limited interest in, and awareness of, the Outback and its concerns, so we can perhaps understand that previous generations made no substantial effort to maintain these species. We should now be more aware of the likelihood of further loss and of a responsibility to attempt to avoid it, by managing these lands in a proactive and competent manner.

Although the fate of Outback mammals is the starkest indicator of failed and failing management, there are other signs of dysfunction and degradation. For example, many Outback birds have also declined extensively (Reid and Fleming 1992; Franklin 1999; Franklin *et al.* 2005). Operating at a scale far smaller and even less noticeable than for the mammal or bird fauna, the rich land snail fauna in central and northern Australia is collapsing, with many species now recognised as threatened (Braby *et al*. 2011). There are likely to be many other examples.

7.2. Shared problems: weeds, feral animals, fire

So why have there been declines in a landscape that retains more than 99% of its natural vegetation cover and has been subjected to relatively little destructive land uses? Across most of the world, habitat removal is the major cause of decline and extinction of plant and animal species. But to date habitat removal has been relatively minor in most Outback areas. Another major global threat to wildlife, particularly in tropical forest areas, is unsustainable levels of hunting. But again, this is an inconsequential or non-existent threat for most Outback species.

Instead, the factors most driving the decline of plant and animal species in the Outback are landscape-scale degrading threats – particularly invasive feral animals, invasive weeds and changed patterns of fire – that cause progressive, pervasive change to environments.

From an ecological and conservation perspective, Australia has characteristics shared by isolated islands generally: its native plants and animals have evolved in isolation and may have little capacity to cope with the competition, predation or other threats posed by introduced plants, animals and disease. In the ecologically brief period (about 200 years or less) since their introduction, many such invasive species have had few constraints on their spread or abundance and some are now causing substantial ecosystem-level change (Doody *et al*. 2009).

There are threats to all Australian ecosystems. However, some characteristics of Outback species and ecology render these systems particularly susceptible to pervasive threats. Species in boom–bust environments are vulnerable to threats that compromise their ability to endure or escape the lean times. For example, feral pigs have proven to be effective at detecting, digging up and consuming freshwater turtles and burrowing frogs that bury themselves and become inactive over the long dry season in northern Australia. Feral camels may deplete small waterholes that formerly provided the basis for life for native animals over large areas and extended dry periods. Extensive grazing or fire can eliminate or substantially reduce the abundance of plants whose fruits or seeds may be vital for some native animals during food shortages. Furthermore, there are characteristics of the Outback – most notably its extensive area, variable climate, few effective barriers and limited management resources – that render it particularly difficult to achieve effective control for many threats.

> The factors most driving the decline of plant and animal species in the Outback are landscape-scale degrading threats – particularly invasive feral animals, invasive weeds and changed patterns of fire.

In this section, some of the main threats affecting Outback environments are presented briefly. Many affect not only environmental values but also social, cultural and economic values. Many operate across all land tenures, affecting many land uses, but are particularly incompatible with conservation. Some of the non-native plants and animals in the Outback are accorded value by some sectors and their spread may be encouraged. To such interest groups, these species are not necessarily 'weeds' or 'pests', but rather useful species. Effective processes to resolve such contrasting perspectives are lacking. Nonetheless, although the detail may differ among different interest groups, all Outback sectors have some concerns about weeds, pests and fire.

7.2.1. Weeds

Scientists and agricultural agencies have introduced many plant species to the Australian Outback, with the selection often based on criteria relating to the plant's likelihood of success. Those criteria are often similar to features that relate to the plant's likelihood of becoming a weed. Often these introduced species came from comparable climates or environments in other continents, they were particularly vigorous and they had high reproductive outputs. Indeed, in a recent study, titled 'It was no accident ... ', CSIRO's Garry Cook and Lesley Dias showed that from at least the 1950s, there was a well-funded and ambitious plan to transform large Outback landscapes from native vegetation through the introduction and spread of a broad range of plants, mostly of African origins (Cook and Dias 2006).

Any introduction that might work was given an opportunity: 'the majority of introductions which appear to have the remotest chance of being useful in any part of northern Australia are maintained either as living collections or in seed stocks' (Williams 1965). More than 8200 pasture plants were brought to Australia, including more than 2600 grass species, nearly twice as many as there are native grass species (Cook and Dias 2006; Cook 2008). About one-quarter of more than 600 exotic species established in pastoral areas are now considered to be a threat to the natural environment (Martin *et al.* 2006). A set of five such invasive pasture grasses – Gamba Grass, Para Grass, Olive Hymenachne, Perennial Mission Grass and Annual Mission Grass – has recently been listed under national environmental law as a key threatening process to Australian biodiversity.

The Outback has now become home to some of the world's worst weeds. These have transformed extensive areas not only near their points of origin or disturbance but also in some otherwise remote and natural landscapes. It is almost inevitable that their distribution and impacts will increase considerably. For example, distributional modelling has demonstrated that almost the entire Outback – with perhaps the exception of the highest rainfall areas – is likely to be suitable for the spread and dominance of Buffel Grass – a native of Africa and Asia. This invasion has been greatly facilitated by the introduction, production and orchestrated dissemination of a wide range of distinct cultivars, each designed or adapted to flourish in different environmental conditions, allowing the species as a whole to be successful across almost the entire chequerboard of environmental conditions in the arid and semi-arid Outback (Lawson *et al.* 2004).

> Gamba Grass could spread across all northern tropical Australia, and its rate of spread is among the highest of any invasive plant in the world.

In a recent review, Tony Grice and other CSIRO colleagues noted the mechanisms by which invasive grasses could transform Outback environments:

'Morphological, physiological, and demographic traits of transformer invasive grasses enable them to sequester a large proportion of the resources available to the community that they invade and so dominate the vegetation or, at least, the ground stratum of the vegetation. This has a number of flow-on effects. ... First, sequestration of resources by an invasive grass alters the resources (e.g. water, nutrients, and light) available to other plant species. As a consequence, the plant species richness of the invaded community declines. Second, the loss or reduction in the abundance of some plant species in the invaded community alters the resources available to other organisms. Third, dominance by the invasive species is likely to alter the structure of the invaded community. The structure of the vegetation … influences its suitability as habitat for wildlife. The impacts of invasive grasses can also be considered in terms of their effects on ecological processes. Invasive grasses might influence water and nutrient cycling and where nutrients in particular are stored in the system. These resource effects and structural changes may, in turn, alter the disturbance regimes of the invaded ecosystem. Invasive grasses might also alter grazing regimes through their different palatability to herbivores, or fire regimes through their influence on the timing and/or amount of fine fuels present' (Grice *et al*. 2013).

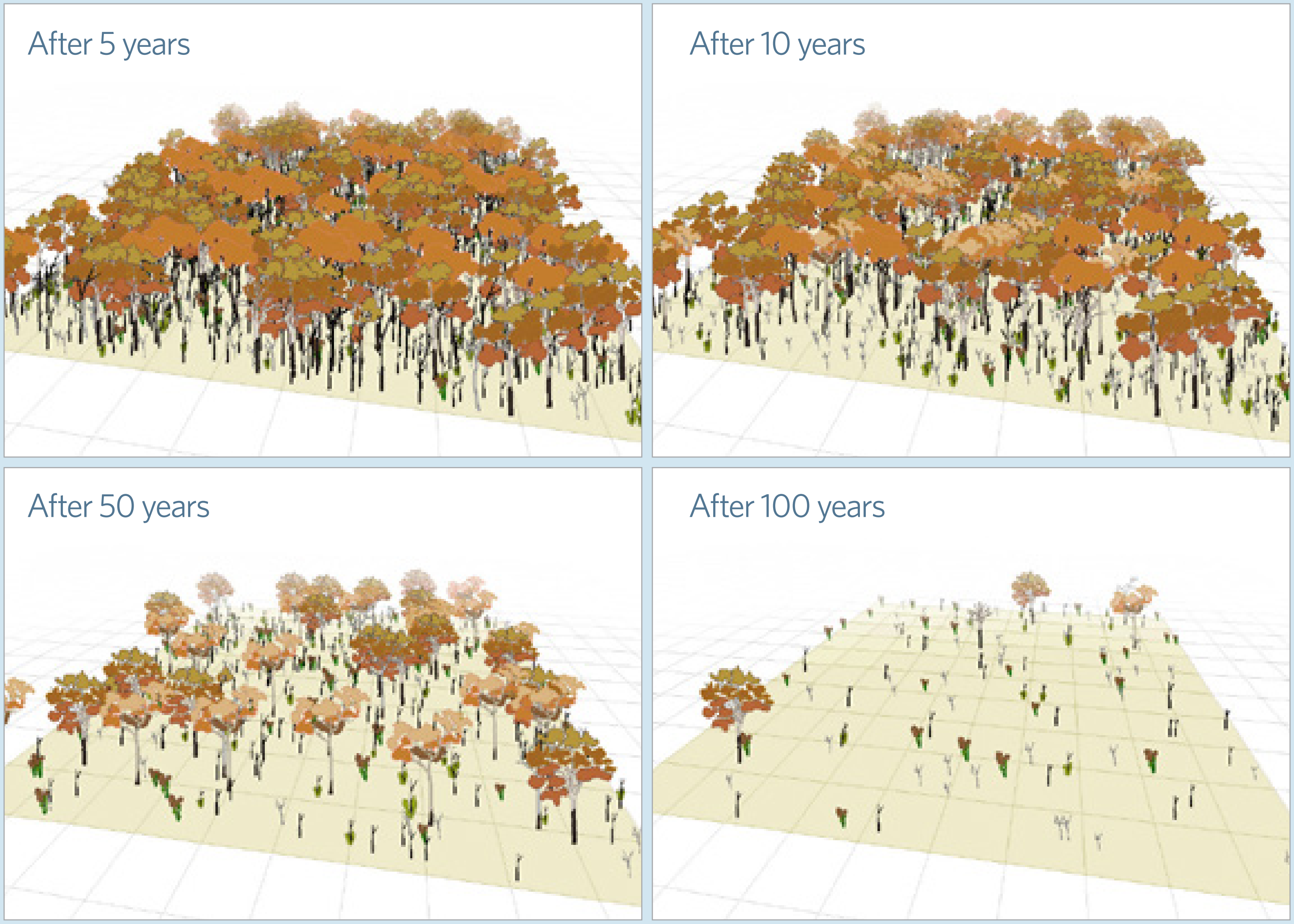
The best documented of these detrimental impacts is the role of invasive pasture grasses in changing fire regimes, typically by increasing the intensity, frequency, and extent of fires. In turn, such fire regimes may create conditions better suited to the invasive grasses than the native vegetation, leading to a destructive vortex that can cause permanent and marked change in the structure and composition of vegetation across large areas. The weeds most capable of such environmental transformation are Gamba Grass in the high rainfall savanna woodlands and Buffel Grass in lower rainfall Outback areas. Fuelled in part by a remarkable capacity to extract and use soil nutrients, Gamba Grass produces exceptional biomass – more than 15,000 kg per hectare, compared with 3,000 to 5,000 kg per hectare typical for native grass understoreys (Rossiter *et al*. 2003; Williams *et al.* 2003). It grows to at least four metres, is closely spaced and vigorous. It tends to dry out later than most native grasses, so forms a dense layer of highly flammable herbage well into the dry season.

Fires in areas with Gamba Grass typically burn from five to twenty times more intensely than in comparable areas without it. Whereas 'normal' dry season fires in these savanna landscapes have few or no impacts on the tree layer, fires fuelled by Gamba Grass kill trees (Rossiter *et al.* 2003). Repeated incidences of such fires can reduce tree cover by 50% in 12 years (Petty 2013), and modelling has indicated that Gamba Grass invasion of savanna woodlands has the potential to turn the diverse woodlands of northern Australia into vast monocultures of African grass (Williams *et al.* 2009b) (Figure 47). Gamba Grass could spread across all northern tropical Australia, and its rate of spread is among the highest of any invasive plant in the world (Petty 2013).

Some noxious introduced weeds such as Gamba Grass (above), which threatens northern savannas, can transform ecosystems. Gamba Grass grows to over two metres tall.

Figure 44

FLAMES Model Simulation of Change in a Savanna Woodland Structure Due to the Spread of Gamba Grass and Its Interaction With Fire



Source: Modified from Williams et al. 2009b

Figure courtesy of Adam Liedloff, CSIRO Darwin.

In arid and semi-arid Outback areas, Buffel Grass has a parallel ecological impact, although the total biomass and fuel loads it has created are less than for Gamba Grass, and the arid and semi-arid climate renders fire less frequent. As with Gamba Grass, Buffel Grass fuels fires of higher intensity and greater impact. Likewise, Buffel Grass itself is advantaged by such higher-intensity fires (Schlesinger *et al.* 2013).

'[Buffel Grass] is often first to re-emerge on ash beds, hence forming a positive feedback loop which favours its own regeneration, and modifies the invaded system irreversibly' (Marshall *et al*. 2012).

Although it has an extremely wide habitat tolerance, Buffel Grass is particularly vigorous and dominant in relatively wet parts of central Australia, such as alongside creeks, a part of the landscape pivotal to broader ecosystem functioning. In such areas, fires fuelled by Buffel Grass may damage or kill River Red Gums (Friedel *et al*. 2006), probably the most important hollow-bearing tree across extensive arid and semi-arid areas (Colloff 2014).

Buffel Grass is an invasive species that has direct impacts on plant and animal species, and also accumulates as fuel to exacerbate the frequency and severity of fire. This stand of Buffel Grass is on Gunnerside Station, Hughenden, Queensland.

In addition to impacts due to more destructive fires, invasive grasses directly compete with native vegetation. Typically, areas now dominated by invasive pasture grasses retain substantially fewer native plant species than areas not invaded (Franks 2002; Clarke *et al*. 2005; Jackson 2005; Smyth *et al*. 2009). In turn, such reduced floristic diversity diminishes the variety and continuity of resources available to animals, so the ecological system itself becomes simplified and previously characteristic native species may decline or disappear. The impact is manifest not only at the ground layer; the intense fires fuelled by invasive grasses are more likely to reduce the abundance of trees that supply hollows and other resources for a wide range of wildlife species (Marshall *et al.* 2012). Furthermore, the density and bulk of invasive grasses may also inhibit movement and foraging efficiency for many ground-dwelling animals.

These impacts are realised relatively quickly after colonisation by invasive pasture grasses. But there may also be long-term and irreversible impacts because many invasive grasses use more soil nutrients and water than native vegetation. Over decades, they are likely to run down the soil-nutrient capital, typically already limited in most Outback environments (Rossiter-Rachor *et al.* 2008; Rossiter-Rachor *et al.* 2009).

The proliferation of invasive pasture grasses also substantially increases the greenhouse gas emissions arising from fire and reduces the capability of ranger groups and other landholders to manage fire. Recent modelling suggests that the economy of carbon-management schemes in the savanna landscapes may be fatally subverted by the impacts of fire-promoting grassy weeds such as Gamba Grass (Adams and Setterfield 2013).

There are many weeds in the Outback in addition to invasive pasture grasses. In the north-east Outback, but spreading rapidly, Rubber Vine has invaded about 700,000 hectares of riverside vegetation and floodplains, densely entwining trees and eventually killing and toppling them (Garnett *et al.* 2010). Mimosa, Prickly *Acacia* and Mesquite have invaded millions of hectares across many Outback regions, forming dense spiny thickets in grasslands and wetlands. Noogoora Burr has invaded over two million hectares, including large sections along the Fitzroy, Ord and Victoria rivers. Athel Pines form dense stands along inland rivers, depleting waterholes, excreting salt that kills plants beneath, changing river-flow patterns and causing bank erosion. Most Outback environments are now affected to some degree by weeds (Martin *et al.* 2006).

7.2.2. Invasive feral animals

Many animal species have been introduced deliberately or inadvertently to Australia, and many of these have become serious problems in the Outback. As with non-native plants, some affect not only environmental values but also have economic costs to agriculture and other industries. As with non-native plants, some introduced animals are valued by some people and sectors in the Outback, but are unwanted by other people and bring detriment to other values.

> Across substantial areas of the Outback, pests may now be the most abundant animal species, exerting an ecological impact that considerably surpasses that of individual native species.

Feral animals may be detrimental in different ways, including through competing with native animals, consuming native plants or preying on native animals, degrading water sources, soil and other resources, spreading novel diseases and – notably in the case of the Cane Toad – poisoning native predators.

There are now many feral animal species in the Outback, and almost all areas are occupied by some pests. Probably the only exceptions are some small, remote and little-visited islands, but even many of them now support at least some pest invertebrate species (Woinarski *et al.* 1998). Across substantial areas of the Outback, pests may now be the most abundant animal species, exerting an ecological impact in many regions that considerably surpasses that of individual native species (Table 5).

A brief account of some of the most significant Outback feral pest species follows.

Introduced predators

Cats were introduced to Australia with the first European settlement in 1788. Foxes were introduced in the mid-nineteenth century. Both spread rapidly and became extremely abundant across most habitats. Foxes are now found throughout the arid and semi-arid Outback – but not in most of the tropical north – and feral cats occur across the entire mainland Outback and on many islands.

The introduction of these two species helped cause one of the world's greatest conservation catastrophes – the extinction of about 20 species of the highly distinctive Australian mammal fauna, mostly from central Australia, and the decline of many other species, particularly of birds and mammals. Although much of this impact occurred soon after their spread, the detriment is continuing, with ongoing decline (or failure to recover) of many native species and the failure of many attempted conservation management actions (particularly reintroductions) because of predation by foxes and cats (Christensen and Burrows 1994; Frank *et al.* in press). A recent study at the Australian Wildlife Conservancy's Mornington Wildlife Sanctuary in the central Kimberley showed that individual feral cats occupy a home range of about 3 km^2 and eat an average of five to twelve native vertebrates per night (Anon 2012/13). Extrapolated across the

Table 5

Estimated Population Size and Biomass of Native Vertebrate Species (Text in green) and Introduced Feral Species (Text in brown) in the Northern Territory

Species	Estimated NT population	Total NT biomass (tonnes)
Singing Bushlark	6 million	120
Little Red Flying-fox	2 million	900
Magpie Goose	2 million	4,800
Barramundi	(not reported)	6,500
Feral cat	3 million	10,500
Saltwater Crocodile	100,000	12,000
Cane Toad	92 million	13,800
Human	237,800	14,268
Agile Wallaby	982,080	14,731
Red Kangaroo	102,000–510,000	4,590–22,951
Feral pig	750,000	41,250
Feral donkey	150,000	48,000
Feral horse	300,000	105,000
Feral camel	340,000	272,000
Feral water buffalo	100,000–340,000	90,000–306,000
Cattle (excluding feral cattle)	1.9 million	1,425,000

Source: Woinarski 2014

Table design by The Pew Charitable Trusts

A feral cat with a captured Brush-tailed Phascogale. About 15 million feral cats are estimated to be in Australia, including all mainland Outback environments and many islands. On average, they can eat 5 to 12 native vertebrates per night, making them the major cause of the decline in many native mammal species.

Warddeken Ranger, Garreth Pamkal, holds a feral cat he shot during a night patrol in Arnhem Land, in the Northern Territory. Cats are the only feral predator in the Warddeken Indigenous Protected Area and rangers have identified their control as a priority concern.

Kimberley, this suggests that there are about 100,000 cats in this region, killing at least half a million native animals per night. This is likely to be an unsustainable predation pressure for many native species.

> Extrapolated across the Kimberley, this suggests that there are about 100,000 cats in this region, killing at least half a million native animals per night.

Baiting is the most common control method for foxes and can be highly effective if maintained and if baits are administered at sufficient density. While there are large areas in Australia with such programs, only a small proportion of the Outback range of the fox has such programs, largely because of budgetary constraints. For feral cats, baiting and trapping have been less successful, and there are no long-established effective control programs in the Outback. However, recent innovations with bait type and refinement of baiting protocols have shown promising results (Christensen *et al.* 2013).

Predator-proof exclosures are being increasingly used as an alternative or complement to baiting and are used to protect remnant or reintroduced populations of threatened mammals. There are some notable examples in the Outback, including the Arid Recovery program near Roxby Downs in northern South Australia and Scotia Sanctuary in far western New South Wales. Many demonstrate remarkable success in increasing the population of reintroduced threatened mammals (Anon 2013).

Feral herbivores – stock (and others) gone wild

In almost all Outback areas there are now one or more introduced grazing mammals. The few exceptions are mostly small islands and some of the least-vegetated desert areas. In some Outback areas, including conservation reserves, the density of these pest mammals is comparable to that of livestock on pastoral properties (Bradshaw *et al.* 2007). Such densities are sustained because the larger pest species have few or no predators in the Outback, many can survive on very low nutrient plants (Choquenot 1991) and are relatively generalist grazers, and because they have a relatively high reproductive output.

The most abundant and widespread are feral cattle, horses, donkeys, camels, and goats. Feral deer species are also found in some areas, and their abundance and distribution are increasing (Moriarty 2004). Feral pigs occur across much of the tropical and semi-arid Outback. Two smaller introduced herbivores, the Rabbit and the House Mouse, are also widespread.

Their impact is amplified by a simple mechanical factor: most are hard-hooved and thus more readily trample and degrade soil, ground vegetation, and water sources than the relatively soft-footed native mammals that have long been the dominant vertebrate grazers of the Outback environments. The herding behaviour of many of these pest species increases this impact, as large numbers of relatively heavy animals aggregate in preferred foraging areas. In contrast, most native mammal herbivores are generally much lighter, and are solitary or occur in much smaller groups.

Beyond simple physical degradation of environments, this set of pest species also imperils threatened Outback plant species. It facilitates the spread of weeds, reduces the availability of water sources, and reduces the abundance and diversity of plant resources, such as foliage, seeds, flowers, and fruits, for native animals. It also may introduce and spread disease, trample and destroy the shallow burrows used for shelter by native animals, and increase predation pressure on native animals by reducing vegetation density.

Because of their broader diets, feral pigs have even more substantial and varied environmental impact. They consume the eggs and young of ground-nesting birds and reptiles (including of threatened marine turtles), fallen fruits, native tubiferous plants such as yams, and aestivating frogs and freshwater turtles to the extent that they greatly reduce the population viability of some native species (Fordham *et al.* 2006; Fordham *et al.* 2008). They cause soil compaction and erosion, alter drainage patterns, and create wallows. On Cape York Peninsula, they cause 'kilometres of deep diggings devoid of all vegetation' (Norris and Low 2005).

The European Rabbit is one of the most damaging introductions to the Outback. Even in low numbers, rabbits can eat out preferred plants and keep them from regenerating. In high numbers, they denude the land and ringbark trees (Bird *et al.* 2012). At many Outback sites, they may be responsible for much of the grazing pressure on vegetation (Mutze 1991).

Some small herbivore pests, particularly rabbits and House Mice, may also indirectly lead to increased predation pressure on native species. At climatically favourable times, very high numbers of rabbits and House Mice may support very high densities of both native and non-native predators. The predators also prey on native animals, and this predation pressure may be magnified if the predator abundance 'over-shoots' that of rabbits and House Mice and if the populations of these collapse before those of predators (Pech *et al.* 1995).

Australian scientist Tim Flannery provided a vivid sketch of an Outback area, near Lake Ngapakaldi in the Simpson Desert in 1982, wasted by rabbits:

'We continued in silence, carrying tools and water, and I came to appreciate how this most remote of ecosystems had been devastated by European impacts, despite the fact that few Europeans had ever entered it. Too dry to be used for cattle, it had become a paradise for rabbits, and doubtless the foxes and cats that prey on them. They had eaten the place alive, and all that was left of the native mammals that had thrived fifty years earlier was the odd bone poking out of the dunes. Even the birds and insects had been affected, for the rabbits had stripped much of the vegetation. I have often wondered how this corner of Australia looks now, after calicivirus has purged the place of rabbits, and whether any remnant of those vanished marsupials might have survived to enjoy the arid paradise that, I hope, has sprung up in its wake' (Flannery 2005).

These invasive pest species affect not only environmental values. Camels and buffalo wreck fencing and other infrastructure. Many pests consume much of the vegetation and reduce that available to livestock. Pigs consume and damage crops. Unmanaged feral stock may host and spread disease that could cause calamitous economic impacts for pastoralism or human health. Some pests – particularly but not only camels – degrade and diminish water sources on which some Outback communities depend or which are important cultural features. Many large pests may be road hazards, and collisions of vehicles with feral animals are common across the Outback. In large numbers, some of these pest animals also increase greenhouse gas emissions by belching methane and reducing plant biomass.


Stephane Lemaire

The introduced Asian Water Buffalo, such as this pair on the Bamarru floodplain in the Northern Territory, is widespread in the Top End, where it can cause severe damage to wetland vegetation and ecological processes.


There are an estimated 300,000 feral camels in Australia, causing severe degradation of water sources and some vegetation types and damage to fences and other infrastructure. A recent collaborative program has substantially reduced their numbers across extensive areas.


The herding behaviour of camels and hard-hooved feral herbivores increases their impact on vegetation and soils, as large numbers congregate in preferred foraging areas. They can also present a road hazard, with collisions between vehicles and pest animals common across the Outback.


Throughout the tropical north and parts of the semi-arid zone, feral pigs, shown here in the Vergemont Creek channels on Noonbah Station, Queensland, degrade wetland habitats.

> Toads occupy more than 1.4 million km² of Australia and are spreading into Western Australia at a rate of 60 kilometres a year.

Killer amphibians

Introduced to central Queensland from central America (via Hawaii) in the 1930s, cane toads have now spread throughout higher rainfall areas of Queensland and the Northern Territory, with the exception of some islands, and reached the Kimberley in about 2010. Toads occupy more than 1.4 million km² of Australia and are spreading into Western Australia at a rate of 60 kilometres a year. They will colonise the Kimberley completely within a few years and – if an effective quarantine line is not established – then spread south to the Pilbara. They affect terrestrial and aquatic invertebrate and small vertebrate species through predation or competition. However, the most significant and well-established impact is through poisoning of some vertebrate species that seek to prey on them. The most substantial losses have been reported for the Northern Quoll and several goanna and snake species, which have been eliminated from large areas following toad invasion (Griffiths and McKay 2008; Doody *et al.* 2009).

Invasive ants

Some pests, such as camels and donkeys, are obvious, while others slip under the radar. Largely unnoticed, many non-native invertebrates now occur in the Outback, with impacts varying from relatively benign to severely detrimental. Two introduced invasive 'tramp ants', the Big-headed Ant and Yellow Crazy Ant, may be of most concern. Both form large, aggressive colonies that substantially reduce the abundance and diversity of other invertebrates and also – directly and indirectly – small vertebrates (Hoffman *et al.* 1999). Currently, the distribution of these two ant species in the Outback is relatively limited, but both have the potential to spread extensively across higher-rainfall areas.

Aquatic pests

Pests now occur in almost all Outback environments, and aquatic environments are no exceptions. For example, the Mosquito Fish (Eastern Gambusia) has been introduced to many water bodies in the Outback, in a futile attempt to reduce nuisance mosquitoes. It has spread widely and is now abundant in many Outback wetland systems, preying on and outcompeting native fish and aquatic invertebrates, resulting in substantially simplified aquatic communities. It is a particular threat in mound springs, because these support fish and other aquatic species found nowhere else (Kerezsy and Fensham 2013).

7.2.3. Fire

Fire is a conspicuous and near-ubiquitous feature of the Outback. It is a natural ecological process. It is a threat to biodiversity and to human safety and infrastructure, a major tool used by land managers. It is also a distinctive and enduring part of Aboriginal lore and cultural responsibility. Given these characteristics, it is a complex and contested factor (Edwards *et al.* 2008) and we consider fire within different contexts in different parts of this report. Here we consider the threat of fire to natural and other values.

Henry Cook

Northern Quolls were once widespread throughout Northern Australia but are now threatened by expanding populations of the poisonous cane toad.

Krystal Kelehear

Cane toads have contributed to major declines of several native species across extensive areas. Their range continues to increase in Outback areas, for example: they are spreading into Western Australia at a rate of 60 kilometres a year.

> Fire regimes have changed across most of the Outback over the last few generations, mostly to regimes marked by more extensive and high-intensity fires with short return times.

Fire regimes have changed across most of the Outback over the last few generations, mostly to regimes marked by more extensive and high-intensity fires with short return times. Very large fires (burning areas of more than 10,000 km^2) and an extensive total burnt area (>300,000 km^2 per year) are now a feature of monsoonal northern Australia (Williams *et al.* 2009a; Williams *et al.* 2009b; Yates *et al.* 2009). Fires exceeding 10,000 km^2 in extent are increasingly common in the spinifex grasslands of central Australia (Turner *et al.* 2008). In many higher-rainfall regions in northern Australia, less than 5% of any area remains unburnt for longer than five years (Andersen *et al*. 2012). Conversely, in some Outback regions – particularly pastoral areas with high stocking rates – fire is now more rare in the system because it is suppressed. This suppression is because fire is considered to be a risk to infrastructure and stock and because it may reduce the availability of fodder, and fires may also be less likely to occur because high grazing pressure reduces the amount of vegetation and hence plant biomass (fire fuel).

What are the consequences of these changes? For biodiversity, it is largely the disintegration of a long-established ecological state or equilibrium, whereby at least some plant and animal species long-attuned to the previous fire regime(s) are disadvantaged by the current replacement regime(s). One group of the most disadvantaged species are 'obligate seeder' plants that require a minimum period between successive fires. These plants are killed by fire and normally recover post-fire from shed seed, but are susceptible if their time to maturity is greater than the between-fire interval. This may not be a fatal problem if fires are patchy – enabling some individual plants to escape this death trap, or small – so that in the broader landscape some pockets of plants escape the repeated fires. However, across most of the Outback, fires are now more extensive and less patchy, and losses of a species from any site aggregate to landscape-scale losses and regional extinctions. Many of these obligate seeder plants are now among the most threatened species in the Outback. Animal species that depend on these plants will inevitably follow the same trajectory. Leichhardt's Grasshopper, which feeds on the fire-sensitive shrub *Pityrodia* species, is a notable case from the sandstone heathlands of Kakadu and other Top End ranges.

Frequent, extensive and high-intensity fires also homogenise Outback landscapes by reducing the extent of fire-sensitive vegetation. This is most evident for rainforest patches in higher-rainfall areas and for some *Acacia* woodlands and shrublands. One extreme case is the diverse array of snails in the Outback, many of which are restricted to tantalisingly small ranges – the leaf litter under a few fig trees on a single hill in central Australia, a few hectares of an isolated patch of limestone in the Top End, or a rainforest patch of less than 10 hectares in the Kimberley. These very restricted habitats can be destroyed in a single fire. These snail species are living perpetually in proximity to extinction, and that risk becomes extreme when fires are more frequent, intense and extensive (Braby 2011).

In monsoonal northern Australia, fire affects the woodland structure. In frequently burnt areas, most savanna woodlands have a distinctive structure, of trees and grass. However, if these areas are unburnt for five or more years, they may develop an increasingly dense and diverse shrub layer. Many of the shrubby plants that are disadvantaged by frequent fire happen to produce fleshy fruits that are an important food resource for many native mammal species – such as possums and tree-rats – and valued bush tucker in Aboriginal communities (see Spotlight 9). Middens from Aboriginal campsites before and after European contact demonstrate that many of these fruit-producing shrubs were far more abundant several generations ago than they are now (Atchison *et al.* 2005; Atchison 2009). The current fire regime is simplifying these woodlands, driving the decline of shrub species and the fruit resources they produce, and this is contributing to the decline of several native mammal species.

Fire is a natural ecological process that both threatens and supports Outback nature. However, across most of the Outback, fires are now more extensive, intensive and less patchy, posing a greater threat to plants and animals.

The spectacular Leichhardt's Grasshopper is restricted to small areas of heathlands in rugged environments of the monsoonal tropics of northern Australia. It feeds from a narrow range of plant species and these plants are highly fire-sensitive, so the plants and thus the grasshoppers disappear from areas that are too frequently burnt.

Spotlight 9 **Current fire regimes driving the decline of Outback biodiversity: an example – the Brush-tailed Rabbit-rat**

Fires and fire regimes have many different impacts on many different plant and animal species in the Outback. These may be direct (for example, with individuals killed by the fire) or indirect (for example, with individuals starving after fire through lack of food resources in burnt areas), beneficial or detrimental. Where a particular fire regime is detrimental, that detriment will be magnified if the same fire regime occurs across large landscapes, in which case local-level losses may become regional-scale extinctions.

The Brush-tailed Rabbit-rat is one of many Outback species for which the current fire regime is detrimental. It is a beautiful, goofy-looking native rodent, much like a guinea pig sporting a magnificent tail. As with many species of the cryptic Australian mammal fauna, few Australians have ever seen it. Rabbit-rats have fared very badly: two of the three species present at the time of European settlement are extinct. Now the Brush-tailed Rabbit-rat is declining rapidly across its north Australian range.

Fire affects the Brush-tailed Rabbit-rat by destroying its denning sites, reducing its food sources and increasing its susceptibility to predation, with these effects becoming increasingly severe as fire frequency, intensity and extent increase. The Brush-tailed Rabbit-rat dens (shelters during the day) in hollow logs, tree hollows and occasionally in the tangled and prickly canopy of pandanus shrubs (Firth *et al.* 2006). Hollow logs and pandanus crowns are likely to be burnt in fires, particularly those hotter fires of the late dry season, and this may directly kill rabbit-rats. Tree hollows may also be unsafe during fires, as flames 'chimney' through hollow trees. Even if the rabbit-rats survive the fire, the number and quality of den sites will have been reduced by fire (as hot fires also tend to kill, fell and consume hollow trees). Savanna fires destroy the grass cover, with fires burning much of the seed and grass-stem resource that rabbit-rats require as food (Firth *et al.* 2005). Burnt ground also offers far less protection for ground-foraging rabbit-rats from predation by feral cats. If rabbit-rats survive fire, their exposure to predation may be heightened as the shortage of food resources mean that they have to travel more and spend more time foraging in unvegetated burnt areas, increasing their risks of predation.

Fire also affects the timing and amount of grass seed produced. If the entire home range of a rabbit-rat is burnt, then most grasses will produce seed at the same time. This is not very convenient, because it means that there will be substantial periods of food shortage. However, if parts of the home range are unburnt and parts burnt at different times, there may be multiple peaks and hence a more continuous food supply (Woinarski *et al.* 2005).

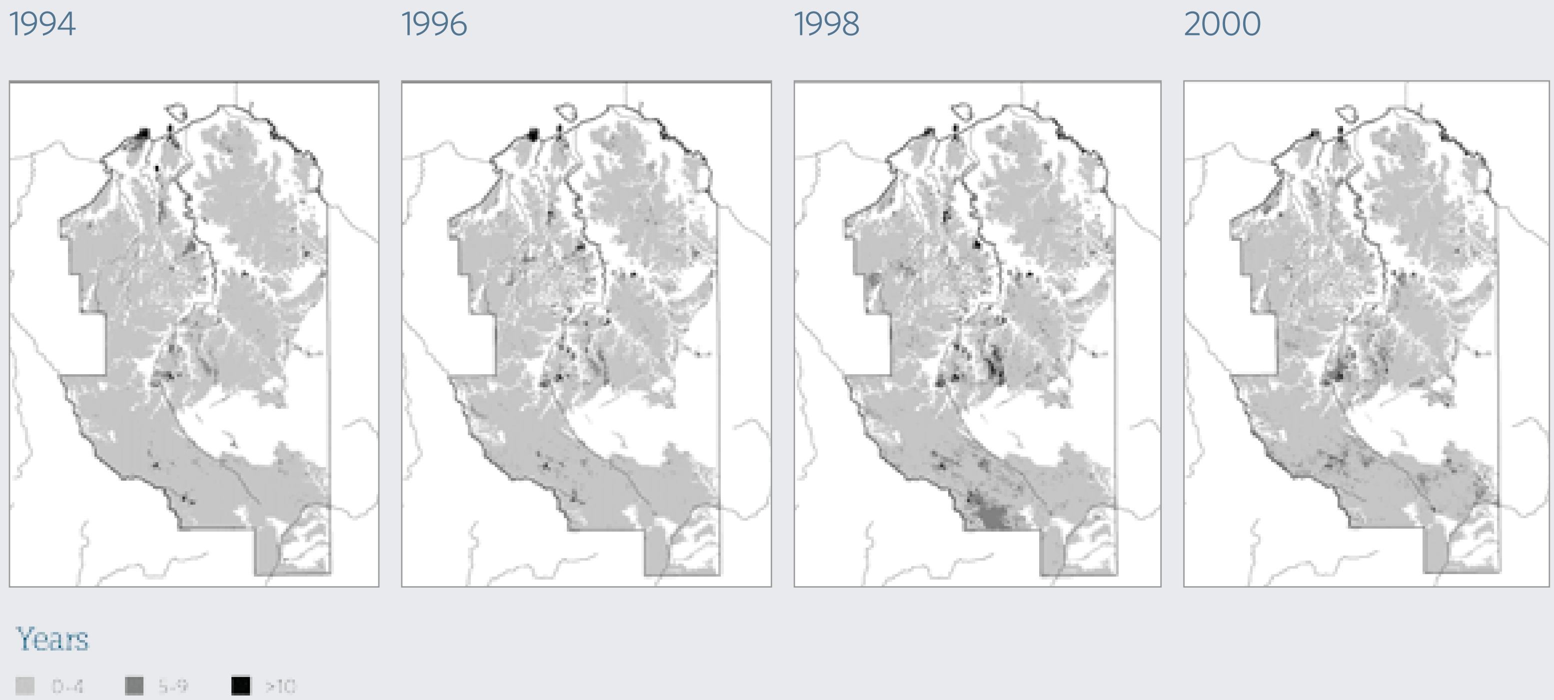
Single fires may have multiple consequences, but the fire regime is even more important. Patterns of repeated fire at short return intervals – for example, every 2–3 years – have compounded impacts because these lead to changes in the plant species' composition and structure, disadvantaging those grass species particularly favoured by rabbit-rats and reducing the abundance, extent and productivity of shrubs that produce fruits. Such regimes may also increase the likelihood of expansion by invasive pasture grasses, increasing their dominance and thereby further increasing the likelihood of fires of even higher intensity.

Given that fire is an almost inescapable factor in the tropical savannas, the best regime for rabbit-rats is one characterised by some 'cool' and patchy fires, in the early dry season, that are of limited extent and that leave much of the area unburnt, with such fires having a return time at any spot of more than three years. This regime, which is presumed to be more or less that practised under Indigenous land management, is now largely replaced by a less considered regime of more extensive, frequent and higher-intensity fires, with fires late in the dry season being particularly destructive (Figure 45).

The Brush-tailed Rabbit-rat is one of Australia's 'old endemic' rodent species. It is restricted to the tropical savannas of northern Australia and is declining rapidly because of changed fire regimes and predation by feral cats.

Figure 45

A Depiction of Fire History in Lowland Eucalypt Forests of Northern Australia



Note: These maps of Kakadu National Park show the time since the last fire, at four dates. Consistently, only a very small proportion of the forest area has been unburnt for more than four years and almost no areas have been unburnt for at least 10 years. (Note that white depicts habitats other than lowland eucalypt forests, and the fire history of these other habitats is not considered here). For species such as the Brush-tailed Rabbit-rat, which prefers forests that are unburnt for at least three years, the current frequent fire regime means that only a very small proportion of the habitat is now suitable, and these areas shift from year to year.

Source: Woinarski 2004

Studies of the ecology and life history of rabbit-rats have been used to model their population-level response to different fire regimes. These studies show that both juveniles and adults are less likely to survive in areas subjected to late dry-season fires than in areas that were unburnt or burnt in early dry-season fires. Modelling indicated that a local population would be certain (100% likelihood) to become extinct within 10 years if exposed to a late dry-season fire every year; would be 97% likely to become extinct if such a fire occurred in only 30% of years; and would be 89% likely to become extinct if there was only one late-dry season fire over that decade. But an absence of fire is also not ideal, as a population in such an area would have a 78% chance of extinction (Firth *et al.* 2010). Persistence was more likely if the site was exposed to some early dry-season fire. Such a regime is not the default; it can be achieved only by careful, strategic and considered management. And to be effective for biodiversity conservation, such regimes must be implemented over large landscapes.

Land managers in Outback regions are increasingly embracing the role controlled burning can play in reducing the incidence of more severe wildfires. This burn was conducted by national park rangers near Nourlangie Rock, in Kakadu National Park.

More-frequent and higher-intensity fires in savanna woodlands also affect the tree layer. Recent modelling has shown that repeated late dry-season fires at return intervals of about three years – as now occurs in some north Australian sites – is likely to greatly reduce the entire tree layer within a few decades (Williams *et al.* 2009b).

A Western Chestnut Mouse captured during a biodiversity survey by the Wunggurr Rangers in the Kimberley region of Western Australia. Studies have found the mouse to be far more abundant in unburnt areas, largely due to the increased predation on native animals by cats, dingoes and owls in burnt areas.

Even without such wholesale woodland structural changes, more-frequent and higher-intensity fires reduce the number of tree hollows, a necessary resource for nesting and shelter for many bird, mammal, reptile, frog and invertebrate species. Such hollow-dependent animal species are more numerous in Australia than in other continents (Williams *et al.* 1999). Frequent and high intensity fires also reduce the abundance of hollow logs and other ground-level shelter sites for animals.

Any fire may directly kill some plants and animals. But the less-direct impacts may be more detrimental. These delayed impacts include loss of shelter and food and increased risk of predation (Andersen *et al.* 2012). If large areas are burnt with high-intensity fires, repeatedly, the resulting high incidence of predation is likely to lead to landscape-wide population decline (Firth *et al.* 2010). Furthermore, the recolonisation of burnt areas by native animals from unburnt areas becomes progressively more difficult as the patch size of the fire increases. If extensive fires are frequent, such species are likely to disappear from large areas (Woinarski *et al.* 2005).

In a study by researchers at Mornington Wildlife Sanctuary in the Kimberley, trapping in unburnt areas and nearby comparable areas burnt by an extensive late dry-season fire found that both the native Pale Field-rat and Western Chestnut Mouse were about 10 times more abundant in the unburnt areas (Legge *et al.* 2008). A subsequent study in the same general area demonstrated that the reduced abundance in burnt areas was not due to mortality directly associated with the fire, but instead to substantially higher rates of predation – by cats, dingoes and owls – in burnt areas than in unburnt areas (Leahy 2013). It was not only that the native mammals were apparently easier for predators to detect and capture in the burnt areas, but also that predators tended to move into and hunt preferentially in these burnt areas.

A recent review of the impacts of current fire regimes and management on birds in the monsoon tropics of northern Australia drew conclusions that are probably applicable across much of the Outback and across much of biodiversity:

' ... much current fire management is failing. We suspect that in part this is because it is untargeted, because it emphasises practice and methodology (e.g. mosaic burning) rather than outcomes, because it is geared negatively (i.e. to apply fire to limit risks of worse fire), because there is so little accountability about getting it wrong, and because the case for fire-driven erosion of conservation values has not been well enough made' (Woinarski and Legge 2013).

7.2.4. Disease, parasites and pathogens

In general, little is known of the incidence, extent and impacts of pathogens and disease in native plants and animals in the Outback, or of their role in structuring ecological processes. One of the few considerations of this issue is a recent review by Ian Abbott, who collated historic documentation – mostly from the late 19th and early 20th centuries – from hundreds of sources that made reference to sick or diseased wildlife in Western Australia (Abbott 2006). Taken together, these diverse sources revealed a consistent pattern of the sudden onset and gradual spread across most of Western Australia, other than desert areas, of an unspecified disease that had substantial impacts on a wide range of native mammals. It led to severe population crashes – in many cases to at least local extinction – for 33 native mammal species. Abbott considered that the disease was introduced with non-native animals transported by ship to the Shark Bay area in about 1875.

> Australian wildlife may be highly susceptible to newly introduced diseases, such diseases may spread widely, rapidly and uncontrollably, and the impacts may be profound.

There has been no comparable historical review or contemporary assessment for other Australian states or territories, or for other animal groups. However, the general conclusion from this study is clear: Australian wildlife may be highly susceptible to newly introduced diseases, such diseases may spread widely, rapidly and uncontrollably, and the impacts may be profound.

7.3. Climate change

Climate exerts a pivotal influence on much of the Outback's ecology and enterprises. Many facets of that ecology and enterprise hinge precariously on an already fickle and extreme climate. Shift the climate a little, and some components of that ecology and enterprise will no longer be viable. The Outback is already a challenging place in which to live. It will become even more so with increase in the intensity and frequency of drought and the number of extremely hot days.

Important components of Outback climates include the onset and duration of the monsoon, the amount, seasonality and reliability of annual rainfall the frequency and intensity of extreme weather events (particularly cyclones, drought and floods), the number of very hot days and the number and intensity of El Niño Southern Oscillation (ENSO) events.

Of course, there have been marked historic changes in the climate of the Outback, and these changes have led to species' losses and increases and broad-scale environmental rearrangements, notably including the development of the extensive dune systems of central Australia. Current and future climate change may be of more marked extent and rapidity. Some components of the climate are already changing in the Outback (see Figures 46, 47) and some environmental changes recently observed in the Outback (for example, increase in the extent of some rainforest patches in northern Australia) may be due to climate change or to its root cause, the increased atmospheric concentration of greenhouse gases (Banfai and Bowman 2006; Bowman *et al.* 2010b).

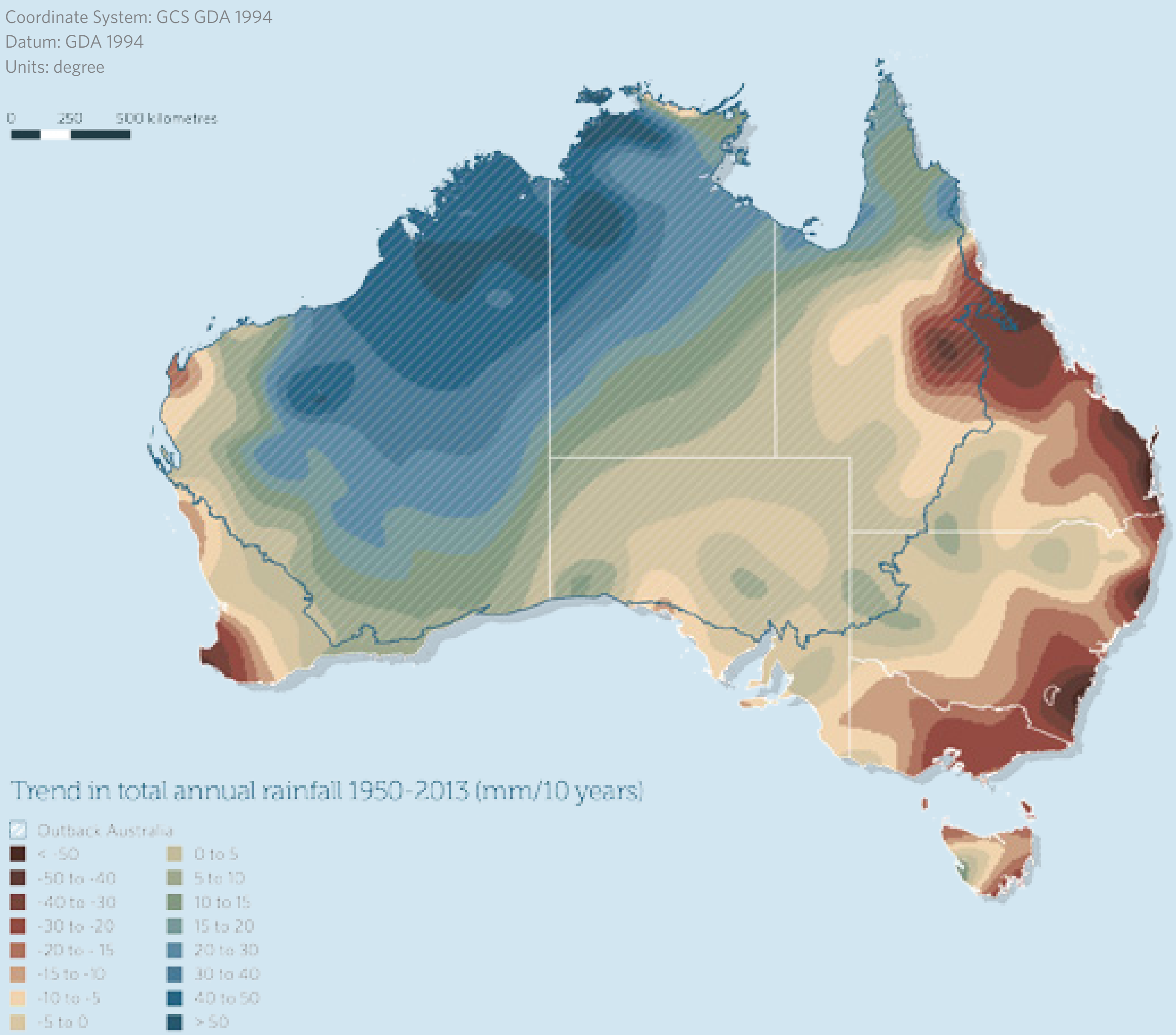
The Outback is hot, and most of it is likely to become hotter. For example, for Darwin, the number of very hot days (>35 °C) is likely to increase from the current 11 per year to 44 per year in 2030 and 227 per year by 2070 (Williams *et al*. 2009b). For central Australia, the number of extremely hot days is also likely to increase markedly and the average temperature is likely to increase by between 0.5 and 4 °C by 2050 and by between 0.8 and 8 °C by 2080 (Pittock 2011). Such an increase will have direct impacts on many species – by exceeding their physiological ability to cope with heat – but it will also have indirect impacts – for example by reducing water availability and increasing the likelihood of extensive and uncontrollable fire. For people in the Outback, the increase in the number of very hot days will affect activity and comfort, compromise some enterprises – particularly horticulture – and increase demands for water and energy.

As evident above in the range of projected changes in average temperatures in central Australia, much remains uncertain about climate change in the Outback and about the ability of Outback species, ecological processes and social systems to cope with such changes.

Species already on the edges of their climatic tolerance, or those that are fire-sensitive, are most likely to disappear or become restricted to refuge areas, which may themselves become increasingly tenuous. The geographic ranges of other species will change. In some cases, species will persist in parts of their current range but disappear from other parts. In some cases, individuals of some species may be able to move across the landscape to track shifting areas of suitable climate. The success or failure of such a response will be influenced in part by the species' dispersal ability, the rapidity of climate change and the extent to which natural environments remain connected. Some species may be able to shift more readily than others. However, it is difficult to predict the responses of Outback species to projected climate change because the critical factors may not relate so much to the impacts of a particular increase in average temperature or decrease in average rainfall, but instead to the incidence and duration of extreme weather events such as droughts and extreme heat waves, and of

Figure 46

Historical Trends in Average Annual Rainfall in Australia



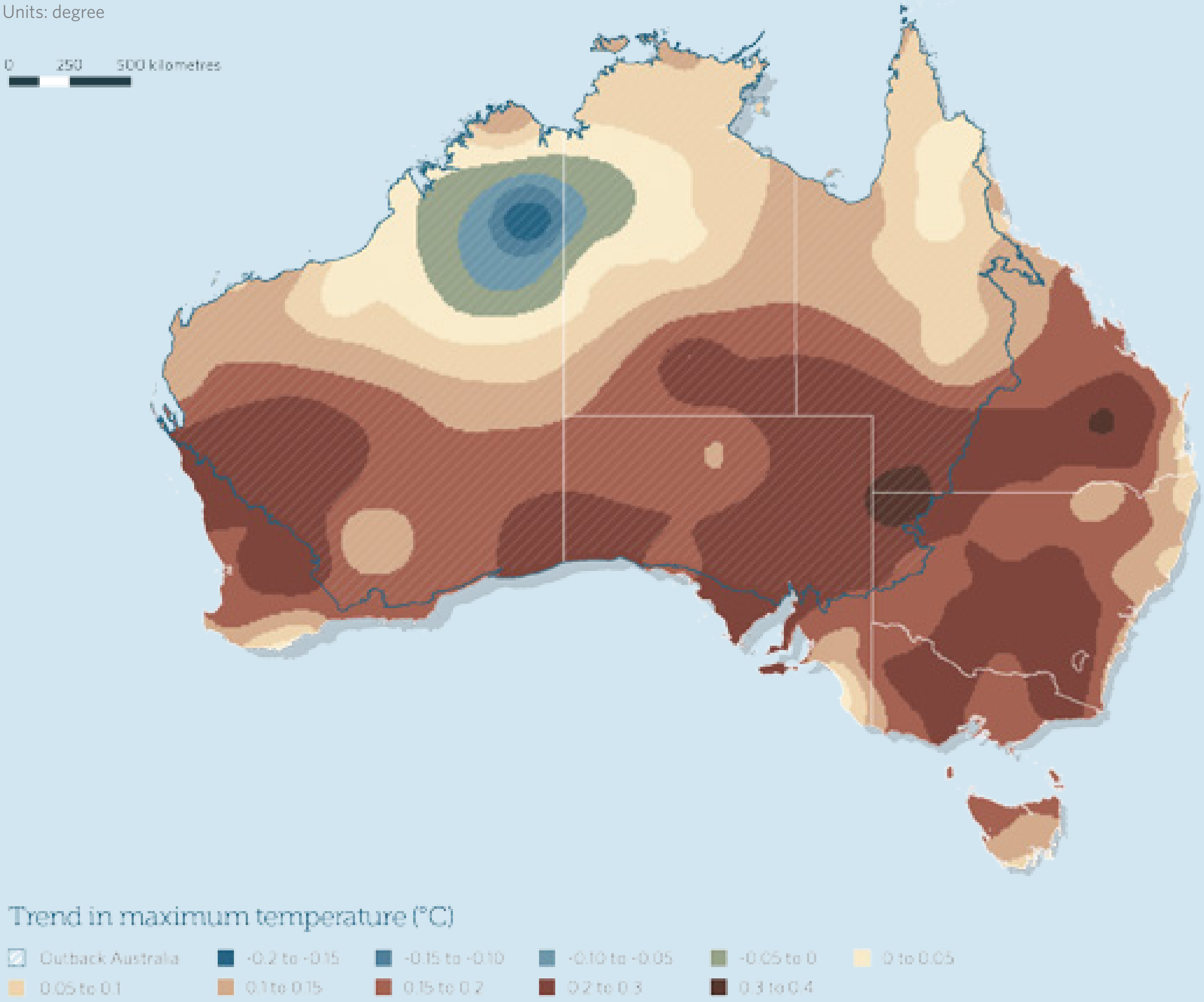
Source: Bureau of Meteorology

Figure design by The Pew Charitable Trusts

Figure 47

Historical Trends in Annual Maximum Temperature in Australia, 1950–2013

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: degree



Source: Bureau of Meteorology

Figure design by The Pew Charitable Trusts

the synergistic impacts of climate change and consequential changes in fire regimes (Garnett and Franklin 2014).

In one recent study, the impact of climate change was modelled for a small set of representative native mammal species in northern Australia (Kutt *et al.* 2009). All of the modelled species are projected to show a marked decline, with almost complete loss of range for four of the 10 species within 16 years (Table 6). These results are salutary, in indicating a likely catastrophic response simply to expected changes in temperature and rainfall, without any consideration of additional impacts due to changes in fire regime that will be associated with this climate change. Furthermore, many plant and animal species are likely to have far narrower climatic envelopes than these mammal species, most of which are relatively widespread, and the future of those more specialised species is likely to be even bleaker.

Table 6

Modelled Distributional Change Due to Climate Change for a Set of North Australian Native Mammal Species

Species	% decline by 2030
Brush-tailed Rabbit-rat	90
Tropical Short-tailed Mouse	60
Black Wallaroo	90
Black-footed Tree-rat	60
Squirrel Glider	50
Northern Brush-tailed Phascogale	90
Brush-tailed Phascogale	50
Common Planigale	30
Pale Field-rat	20
Arnhem Rock-rat	90

Source: Kutt et al. 2009

Table design by The Pew Charitable Trusts

Of course, impacts are not restricted to direct responses of plant and animal species to changes in temperature and rainfall. It is highly likely that even very small rises in sea level – and/or increases in the incidence and severity of storm surges – will swamp many of the existing low-level islands off the Outback coast and inundate the biodiversity-rich and highly productive coastal floodplains of northern Australia, given that these are remarkably flat and barely a few metres above sea level. Such inundation will destroy many of the most important wetlands and waterfowl-breeding sites in the Outback and jeopardise the viability of many species associated with this environment (Traill *et al*. 2011).

Drought has been a catalyst for the decline of many Outback plant and animal species, especially when accompanied by other pressures, such as pastoralism. If it is particularly severe or frequent, it may lead to regional population loss and extinction (Barnard 1917; Barnard 1925; Barnard 1927). The likely increase in the severity and frequency of droughts in central Australia will sharpen and narrow the ecological knife-edge onto which many Outback plant and animal species cling and heighten the conflict between human enterprise and wildlife conservation as pressure on water sources and drought refuges escalates. Increases in other extreme events – possibly including severe cyclones – will also affect infrastructure, regional economies and the viability of some Outback communities.

> The likely increase in the severity and frequency of droughts in central Australia will heighten the conflict between human enterprise and wildlife conservation as pressure on water sources and drought refuges escalates.

A dust storm catalysed by drought blows across a floodplain of the Vergemont Creek channels on Noonbah Station in central Queensland's Channel Country.

Even small changes in rainfall patterns would have dramatic effects on Outback wetlands, river systems and aquatic plants and animals (Morrongiello *et al.* 2011). For example, if intervals between floods increase, the Banded Stilt, which breeds only on large temporary inland wetlands, will breed less frequently, and not at all if the gap exceeds their reproductive lifespan. Conversely, a 10% increase in annual rainfall could transform Lake Eyre into a permanent water body (Kotwicki and Allan 1998).

7.4. Sectoral pressures

In this section, we consider some factors and land uses in the Outback that may share less common ground, in that their operation may benefit one sector but at the expense of other sectors or the nature of the Outback.

7.4.1. Pastoralism

Pastoralism has a venerable and legitimate place in the Outback. Much of the current social and development fabric of the Outback is due to the pastoral industry. Pastoral leases occupy about 40% of the Outback – appreciably more than any other industry sector – with particularly high proportional use of more productive land types, such as the Mitchell Grass tussock grasslands of western Queensland and the Barkly Tablelands. Beef cattle are the main focus of Outback pastoralism, particularly in the north. Sheep and goat production occurs in some Outback areas, particularly in the south (Figures 48, 49). In most Outback regions, pastoralism was the pioneer industry following European settlement and it remains a principal factor in some Outback regional economies.

Reflecting their role as major players in Outback management, many pastoralists contribute significantly and collaboratively to regional-scale management of pests, weeds, and fire. Many pastoralist enterprises rely on native grasses as the foundation for their operation and seek to manage their lands sustainably. Indeed, environmental sustainability in some form is an obligation under pastoral leasehold conditions in all Outback jurisdictions.

But there are environmental costs associated with pastoralism. These costs may be relatively trivial where there are low stocking rates and 'unimproved' pastures. However, they may be severe with high stocking rates, environmental modification (such as tree clearing and the introduction of invasive pasture grasses), water management (degradation of natural water sources or proliferation of artificial water sources), control of dingoes and some manipulations of fire regime. Where pastoralism occurs over a substantial majority of an environment and/or where it overlaps with significant conservation and other natural values, these impacts may be profound. Some impacts may be constrained within a

Richard Woldendorp

Pastoralists on isolated stations, such as this Outback cattle station in Queensland, and small Indigenous communities on 'outstations', are the only residents in huge areas of the Outback. Government policies are needed to encourage people to remain on the land.

Peter Eve/Tourism NT

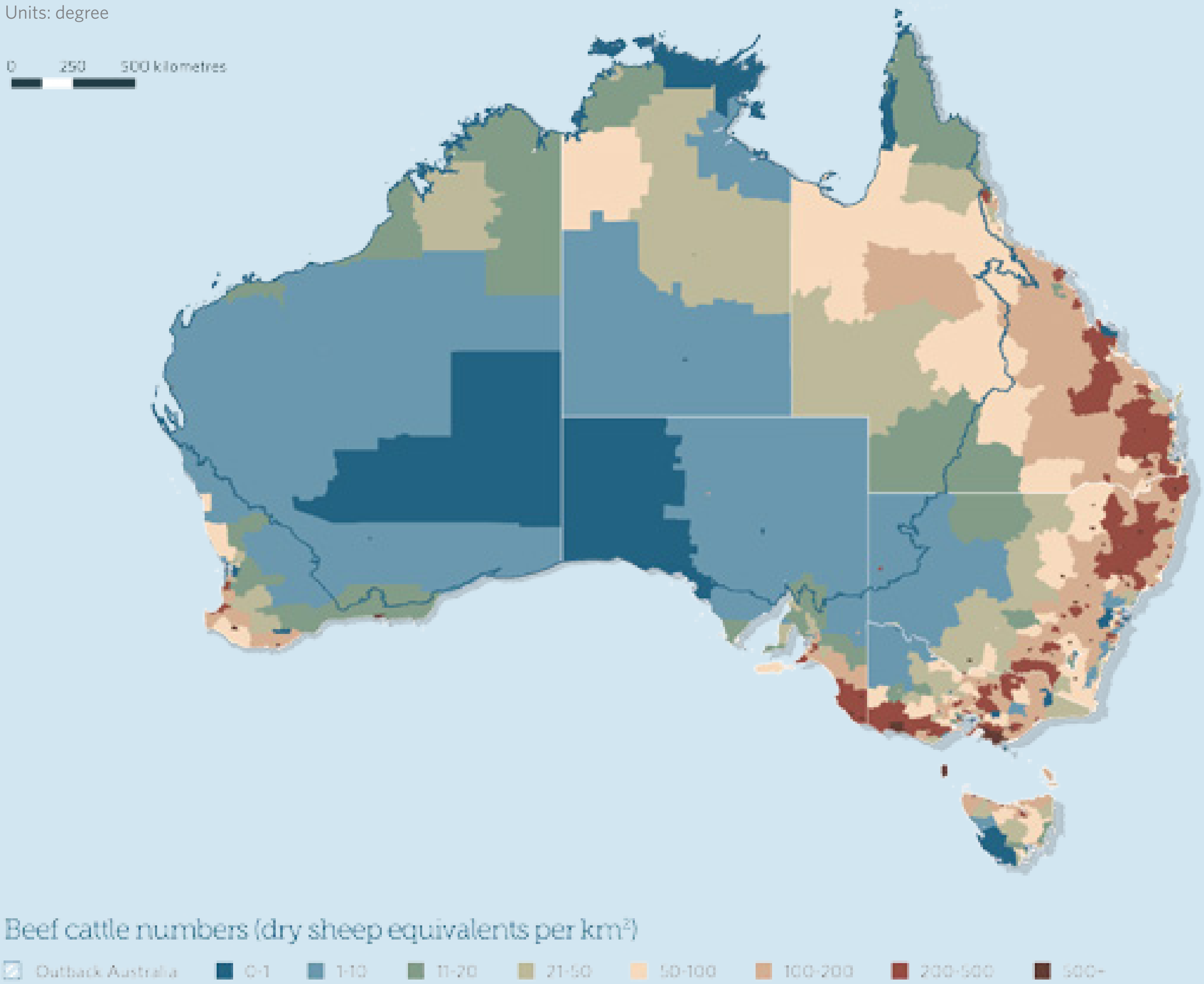
Pastoralism has a long history in the Outback, pioneering settlement and development in most regions. The stockman pictured is moving cattle along the Buchanan Highway in the Northern Territory.

Figure 48

Density of Beef Cattle Across Australia

Note that units are in Dry Sheep Equivalents (DSE) per hectare

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: degree



Source: Based on data from Australian Government Department of Agriculture

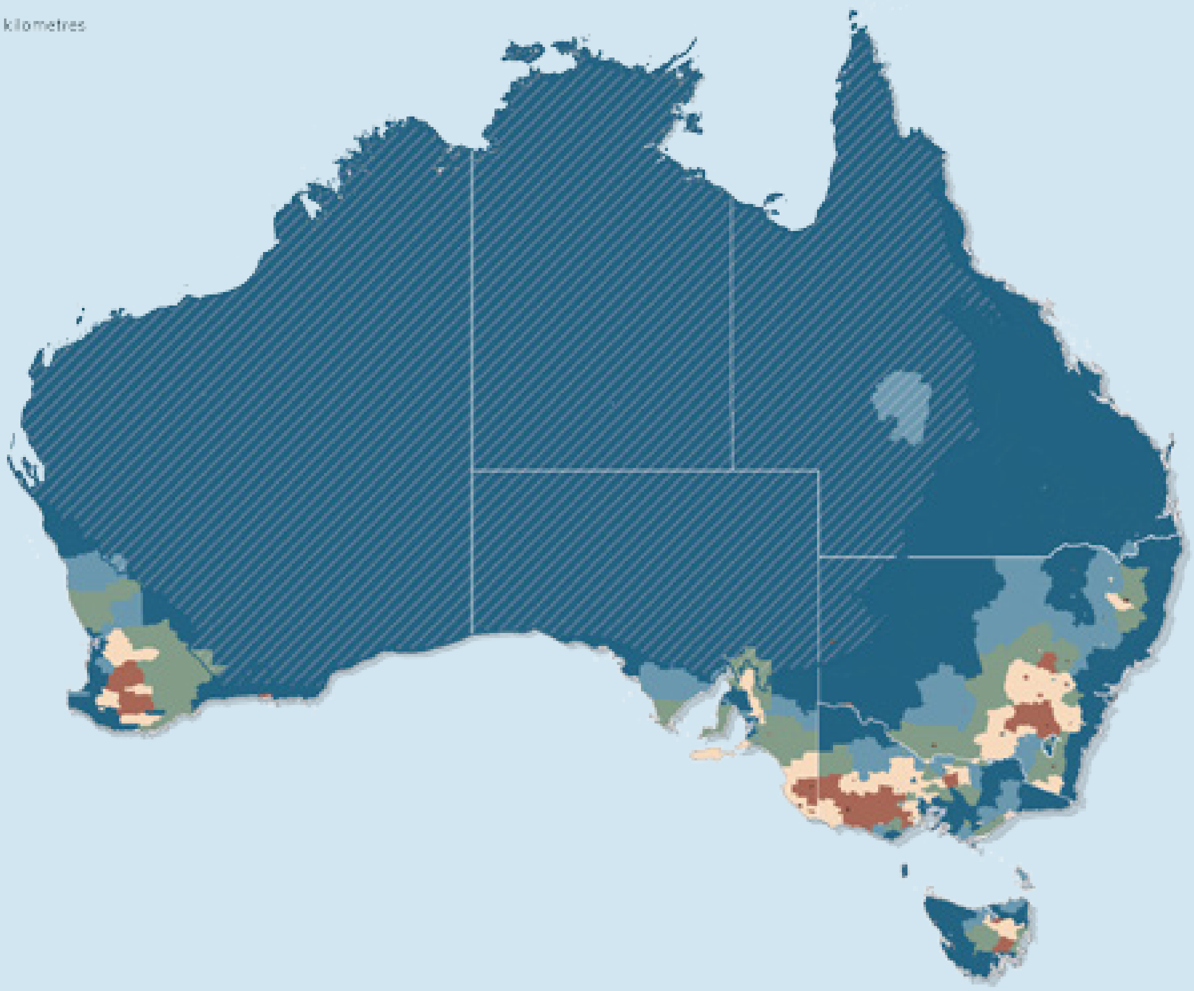
Figure design by The Pew Charitable Trusts

Figure 49

Density of Sheep Across Australia

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: degree

0 250 500 kilometres



Sheep numbers (dry sheep equivalents per km²)

Outback Australia 0-20 21-50 51-100 101-200 201-500 501+

Source: Based on data from Australian Government Department of Agriculture

Figure design by The Pew Charitable Trusts

pastoral property, but some other activities – such as fire management, dingo baiting, introduction and spread of invasive pasture grasses and habitat loss and fragmentation – undertaken within a pastoral property may have consequences beyond the fences. Indeed, in some ways, the impacts of pastoralism on biodiversity and other environmental values are almost pervasive across the Outback landscapes, because feral stock – donkeys, horses, cattle, buffalo, goats and camels – mostly introduced for pastoral purposes now occur widely and abundantly across Outback lands. In many respects, it matters little to native environments and biodiversity whether the introduced herbivore is farmed or not farmed.

> Pastoral leases occupy about 40% of the Outback – appreciably more than any other industry

Pastoral practices and their impacts have varied over time. Historically some areas were exposed to stocking rates that far exceeded sustainable carrying capacity and such practices resulted in marked and enduring degradation, particularly around watercourses, which typically bore the brunt of high stock densities (Start and Handasyde 2002; Novelly and Watson 2007). Eventually, in many regions, herd sizes were substantially reduced in response. However, economic factors may still drive a demand or aspiration to intensify, to seek higher rates of turn-off through greater infrastructure – smaller paddock sizes, more fencing, more water sources – and replacement of native with introduced pastures. Pastoral impacts may also be more severe during extended drought periods.


Sue Vittori

David Pollock and Frances Jones have greatly reduced stock numbers on their pastoral property, Wooleen Station, in the Murchison region of Western Australia. They are closely monitoring the gradual regrowth of grazing-sensitive plants. The couple host Outback farm stays and tours to diversify their income and raise awareness about the importance of giving pastoral land time to recover from over a century of intense grazing.

In general, over a large proportion of the Outback, pastoralists manage the country skilfully to increase its habitat suitability for cattle or sheep. The changes that they make to craft the environment to increase that suitability have substantial collateral detriment to many native species whose preference lies closer to the original habitat conditions (Whitehead and Dawson 2000).

The consequences of pastoralism to biodiversity have been elaborated through cross-fence studies (Woinarski and Ash 2002), grazing gradient studies (Landsberg *et al*. 1997), destocking experiments (Legge *et al.* 2011), documentation of impacts at particular grazing-sensitive sites such as mound springs (Fensham and Fairfax 2003; Fensham *et al.* 2010) and through historical accounts (Barnard 1925; Woinarski and Catterall 2004). One notable recent study at Mornington Wildlife Sanctuary followed the responses of wildlife to de-stocking in a 40,000 hectare area. In this study, native mammals responded rapidly to de-stocking: within three years of de-stocking, they were twice as common in de-stocked areas than in otherwise similar nearby areas grazed by cattle (Legge *et al.* 2011).

Collectively, these studies indicate that the effects of pastoralism on Outback environments and wildlife have been, and continue to be, substantial and diverse. In many environments, cattle eat out the most palatable plants, consigning many to rarity and fostering domination by more grazing-tolerant plants (Landsberg *et al.* 1997). Many grazing-sensitive plant species – such as Cockatoo Grass in the northern Outback areas – may also have an important ecological role, through providing seeds or other resources at times when these are otherwise limiting to consumer animals in the landscape. So, the decline of such plant species may have repercussions across a broader ecological network. Grazing by livestock also reduces the amount of vegetation cover, leaving less food available for native herbivores and reducing the shelter – from predators or weather – for ground-dwelling animals. Trampling by livestock also compacts soil and damages the protective soil crust, damages the shallow burrows of some native mammals and may reduce the nesting success of some ground-nesting birds. In turn, the compacted soil and grazing pressure may cause changes in vegetation, reducing habitat suitability for some native species, and directly affecting fire regimes, with such changes in fire regimes themselves affecting habitat structure and suitability. For example, in the Victoria River floodplain, over-grazing has transformed grasslands to dense woodlands (Sharp and Whittaker 2003). Over time, grazing can reduce overall productivity due to irreversible changes in vegetation and nutrient cycling (van de Koppel *et al.* 1997).

Although some species and ecological functions may bounce back with de-stocking, other changes are difficult or impossible to reverse. In some Outback landscapes, present vegetation communities are now markedly different from pre-pastoralism ecosystems (Allen 2011) and there have been substantial regional declines of many plant and animal species due, at least in part, to pastoralism (Franklin 1999; Woinarski and Ash 2002; Woinarski and Catterall 2004; Franklin *et al.* 2005).

7.4.2. River modification and water extraction

The Outback is notable for the low level of impoundment and extraction of water from its rivers and wetlands. However, there are historic, current and projected threats to environmental values resulting from degradation of aquatic environments and water exploitation.

The major extensive threat to wetlands, water quality and water-dependent vegetation in the Outback derives from degradation due to uncontrolled access to natural water sources by livestock and feral animals, with particularly acute impacts in arid and semi-arid regions with few water sources. In some regions of monsoonal Australia, natural wetland systems have also been transformed to 'ponded pastures', typically accompanied by the introduction (and subsequent spread) of invasive grasses. Such transformation notably reduces the diversity of native aquatic plant and animal species.

> The major extensive threat to wetlands, water quality and water-dependent vegetation in the Outback derives from degradation due to uncontrolled access to natural water sources by livestock and feral animals.

There are also more localised impacts on water quality due to extensive clearing (Dilshad *et al.* 1996) and pollution from mining (Davy 1975; Northern Territory Department of Mines and Energy 1986).

In some cases in the Outback, mining results in even more marked transformation, with a notable recent example being the removal of a 6-kilometre stretch of a major river, the McArthur, and the re-routing of its waters to an artificial channel (URS 2007). Increasingly, some mining activity is also affecting subterranean aquatic systems with potential significant impacts on the often narrowly endemic stygofauna (Boulton *et al.* 2003; Harvey *et al*. 2011).

In many areas of the Outback, groundwater is extracted for pastoralism, horticulture and mining, and in higher-rainfall areas more water is being extracted from rivers. The Great Artesian Basin has been a major source of water, mostly for pastoralism, and the extent of this extraction has

Luke Bayley, Healthy Landscape Manager – Western Rangelands with Bush Heritage Australia, describes the importance of Cryptogramic soil crusts – the thin film of mosses, algae, liverworts, bacteria, fungi and lichens that holds soft soils together and helps prevent erosion in many Outback regions. Bayley is based at Charles Darwin Reserve, a former pastoral property on the northern edge of Western Australia's wheat belt.

resulted in severe loss and degradation in some natural water-dependent ecosystems – most notably the distinctive mound springs. For example, only 20 of 107 mound springs documented in the 1890s are now still active, with the loss of the vast majority attributable to tapping of the Great Artesian Basin by thousands of bores (Fairfax and Fensham 2002).

> Only 20 of 107 mound springs documented in the 1890s are now still active, with the loss of the vast majority attributable to tapping of the Great Artesian Basin by thousands of bores.

Across large areas of the arid and semi-arid Outback, artificial water points have proliferated to increase the proportion of the landscape available to livestock. This development has substantially expanded the area exposed to grazing and reduced the available area for grazing-sensitive plants and animals (Landsberg *et al*. 1997; James *et al.* 2000; Kutt *et al*. 2009).

River flows have been modified in some Outback river systems. The most substantial is the damming of, and water extraction from, the Ord River for broad-scale irrigated horticulture development. The impoundment has led to major changes in the characteristics of riparian and aquatic biodiversity (Start and Handasyde 2002). Irrigated agriculture currently occurs across 34,000 hectares in northern Australia – mostly in the Ord, with smaller areas in the Mareeba–Dimbulah and Katherine–Daly systems – and is worth about A$160 million annually (or 0.8% of northern Australia's region's economic activity) (Northern Australia Land and Water Taskforce 2009). There have been many proposals for substantial increases in the extent of extraction of water from Outback river systems. In lower-rainfall areas – such as for the Cooper Creek system – such extraction will lead to a decrease in the frequency and flooding of lakes and wetland systems nationally important for waterfowl. For waterbirds, and other aquatic life, such extraction will mean that 'boom periods will be shorter and bust periods longer' (Kingsford *et al*. 1999). This consequence of extraction, impoundment and other modification has been recognised to be a particular threat for river systems in semi-arid regions generally:

> 'Floodplain rivers in arid and semi-arid regions may be the most threatened of all river systems because water resource developments typically dampen their most distinctive characteristics—extreme flow variability and 'boom and bust' ecological dynamics' (Arthington and Balcombe 2011).

In higher rainfall areas, the consequences will be comparable but telescoped into an annual cycle: there will be less flow in the low periods of the mid- and late dry season, when the maintenance of flow is most critical.

The intermittent abundance of water in northern Australia has attracted much attention from developers. A recent review concluded that there is no substantial exploitable supply, for a range of reasons. Evaporation rates are very high, making most dams inefficient. Much of the rain falls close to the coast in low-relief lowlands and hence can't readily be captured. Rainfall and flows are very seasonal. Few sites are topographically suitable for damming. And there is little available 'surplus' water for use, in part due to the environmental demands of the limited water availability in the dry season (Northern Australia Land and Water Taskforce 2009).

Stuart Blanch

The most substantial modification of an Outback river system was the damming of the Ord River in the 1960s and '70s, as part of the Ord Irrigation Scheme. The Ord River Dam created Lake Argyle, now one of the world's largest man-made water bodies. Designed to support broad-scale irrigated horticulture in the Kimberley region, the dams have substantially changed the river and its estuary.

The waters of the Great Artesian Basin flow to the surface in parts of the eastern portion of the Outback. These mound springs, such as the healthy Blanche Cup spring near the shore of Lake Eyre South in South Australia (left), can support diverse wetland communities. However, some are at risk from extraction of waters from aquifers. Use by livestock and large feral animals also degrades springs, as this example from the Mulligan group in the Simpson Desert (right) illustrates. The damage was caused by pigs and cattle.

7.4.3. Clearing of native vegetation

Although we have defined the Outback in part by its largely natural state, some Outback areas have been subject to marked vegetation clearing, and there is ongoing pressure for more intensive developments. The most substantial loss of native vegetation in the Outback has been in the Darwin–Katherine region of the Top End, the Ord–Kununurra area, the Carnarvon area, coastal north-eastern Queensland, western Cape York Peninsula, Groote Eylandt, north-eastern Arnhem Land, the Pilbara and the Tiwi Islands.

The impacts of clearing on the Outback's environmental values depend on a range of factors, including the subsequent use to which the cleared land is put, whether the affected land is rehabilitated, the cumulative extent of the clearing relative to the total extent of the region or type of environment affected, the biodiversity value of the area, the configuration of the clearing and the contrast in vegetation structure between the original vegetation and the clearing.

Clearing may also 'contaminate' adjacent uncleared areas. For example, weeds are more likely to enter native bushland close to disturbed areas than areas remote from them (Preece *et al.* 2010). Clearing may also catalyse a curious 'natural' phenomenon in the bird community of nearby uncleared areas. Yellow-throated Miners, a large native honeyeater, are aggressive and communal and in the right set of ecological communities they dominate, relentlessly harassing all smaller native bird species in their range and causing a marked reduction in the diversity and abundance of other bird species (Kutt *et al.* 2012; Mac Nally *et al.* 2014). Yellow-throated Miners occur in woodland areas across the entire Outback, but their impact is usually insignificant unless triggered by habitat degradation or nearby clearing.

In some circumstances, clearing leads to soil loss and sediments entering waterways, which reduces water quality in downstream areas. For example, a study in the Daly Basin estimated that without special conservation methods, soil loss in cleared areas was about 100 tonnes per hectare per year, with most loss associated with the substantial rainfall events of the wet season (Dilshad *et al.* 1996).

This set of 'off-site' impacts means that the consequences of clearing land percolate into and through uncleared areas, substantially extending the 'footprint' of clearing beyond simply that of the area actually cleared.

7.4.4. Mining: mineral and gas production and processing

Mining has a long history in the Outback. Indeed, quarries for stone tools and ochres long pre-dated European settlement. However, the current scale and extent of mining activities is unprecedented (Figure 50). Now, mining is the dominant driver of many Outback regional economies and a major force transforming landscapes and communities.

There are a great variety of mining activities in the Outback. These include extensive strip-mining – involving broad-scale removal of surface vegetation and soil – for bauxite, manganese and mineral sands in north-eastern Arnhem Land, Groote Eylandt and western Cape York Peninsula; gouging of large hills and mesas for iron ore in the Pilbara; uranium mining adjacent to Kakadu National Park; many small-scale shaft mines and fossicking for opals around Coober Pedy; extensive natural gas production in the Cooper and Amadeus Basins and off the northern and western Outback coasts; major silver, lead and zinc mining in the Gulf hinterland of north-western Queensland and nearby Northern Territory; small and large gold mines scattered across almost all Outback regions; large-scale diamond mines in the south-east Kimberley; and a rapidly increasing amount of coal-seam-gas mining in some areas. There are many other mining activities of contrasting scale, history, profitability, regulatory context and environmental impacts. And extending well beyond the nodes of developed mines are vast areas, covering about three-quarters of the Outback, allotted to mineral and gas exploration.

Given the substantial range of mining activity in the Outback, only general issues are considered here.

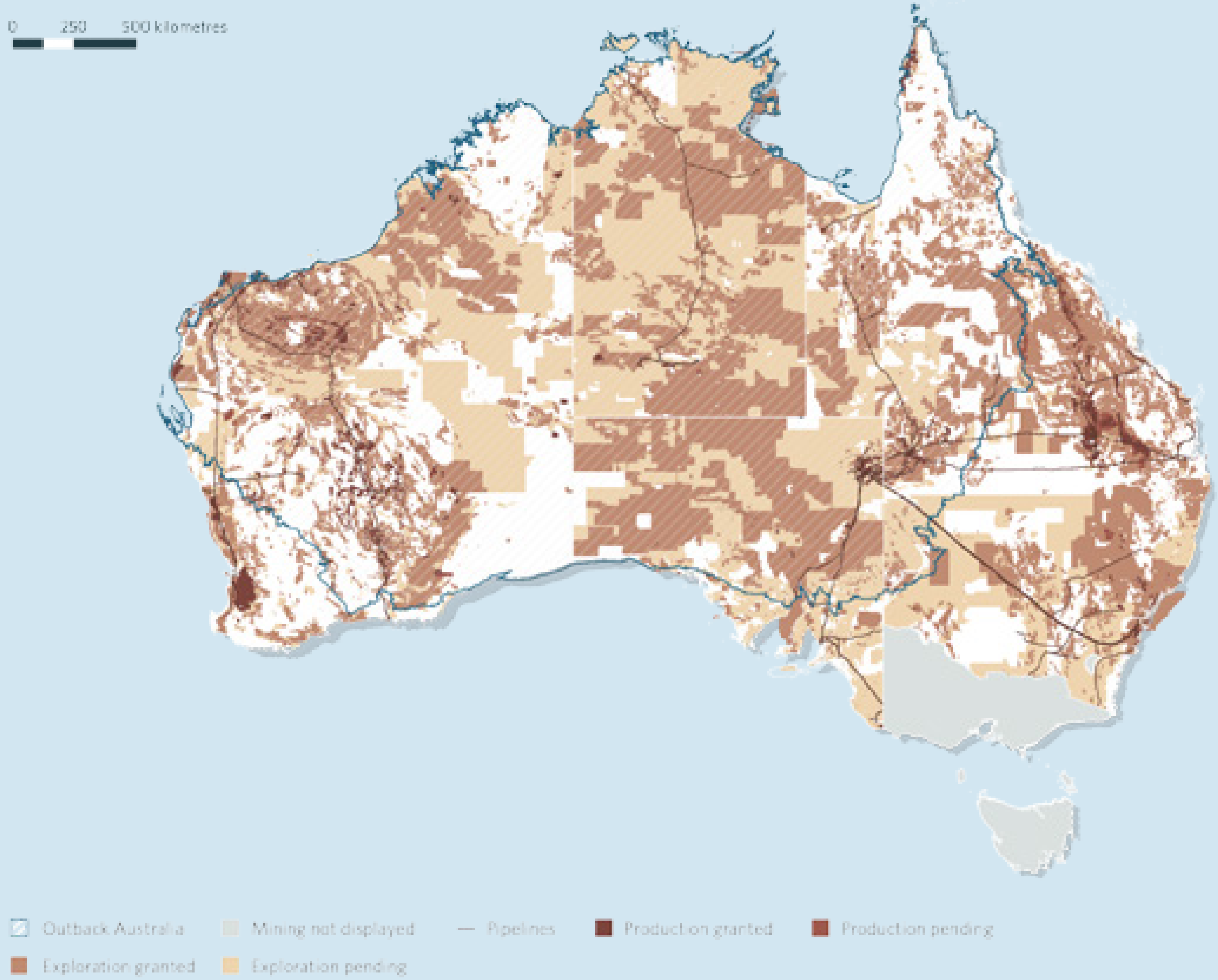
Notwithstanding the vastness of the Outback, there are many Outback plants and animals with very restricted distributions, and many of these species happen to be associated with the same environmental features that make for mineral prospectivity. Notable examples include a suite of highly localised plant species tightly associated with banded ironstone and greenstone formations in Western Australia (Markey and Dillon 2008) and many remarkably unusual subterranean invertebrates and some vertebrates in isolated groundwaters or cavities (Boulton *et al.* 2003; Harvey *et al.* 2011). Even a single small mine may encompass the entire range of such species and destroy its entire habitat. The likelihood of loss of essential habitat increases with the scale of a mine and in areas experiencing multiple and cumulative mine impacts. Many of these species are poorly known and hence not listed as threatened under national legislation.

> An Outback increasingly pock-marked by mines will lose much of its internationally significant integrity, beauty and naturalness.

Figure 50

Extent of Mining Activity Across Outback Areas

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: degree



Source: Derived from information from relevant state and territory agencies

Figure design by The Pew Charitable Trusts

Mining is a key driver of some local economies in the Outback. While mining occurs on less than 1% of the Australian landmass, there are exploration licences across nearly three-quarters of the continent. Mining for iron ore at Mt Tom Price, pictured, in the Pilbara region, in Western Australia, began in 1966.

An Outback freight train takes iron ore to Port Hedland from Fortescue Metals Group's Cloudbreak mine in the Pilbara, Western Australia. Transport infrastructure associated with mining in Outback areas, such as road networks and rail lines, can increase the impact of industrial activity on the broader landscape.

Many mining ventures require large quantities of water to be abstracted, and the use and disposal of such water can affect hydrological systems, aquatic communities and water-dependent ecosystems across considerable areas away from the mine site itself. Furthermore, there have been many severe pollution events, typically involving chemicals used in processing or by-products of the mineral extraction. Heavily polluted tailings dams at mine sites are a notable case, often resulting in large kills of waterbirds attracted to dam sites in arid and semi-arid areas and during dry periods (Donato *et al.* 2008). Such cases affect biodiversity well beyond the mine site itself. Another notable example is the halo of pollution – and consequentially reduced biodiversity – associated with sulphur dioxide deposition around the Mt Isa smelter (Griffiths 1998; Hoffmann *et al.* 2000).

Mines are generally point sources of environmental loss in the Outback. In many cases, their associated infrastructure – rail lines, road networks, ports, processing plants and mining camps – and broad-scale exploration activities increase each mine's impact zone considerably.

There are some Outback areas with conservation or cultural values of such significance, or which are superlative examples of largely natural landscapes, that any mining venture within them is inimical to those core values. More broadly, an Outback increasingly pock-marked by mines will lose much of its internationally significant integrity, beauty and naturalness.

7.5. A medley of threats

Some of the individual threats described earlier in this section have significant direct detrimental impacts on individual plant and animal species, and on ecological communities and processes. But across most of the Outback many threats co-occur, and the overall impact on any plant or animal species, or on any ecological community or ecological process, may arise from some combination of many threats. In many cases, there may be substantial interactions between threats, and the combinations of threats may be operating in such a manner that the overall impacts are greater than simply the sum of individual threats.

An example of multiple interacting threats potentially affecting an Outback species, its habitat and resources is presented in Figure 54. In this case, the main factors governing the population size and reproductive success of the declining Partridge Pigeon are thought to be the availability of food resources and predation pressure. In turn, these are influenced by habitat factors – which in turn are influenced by fire regimes, weeds and feral stock – and the relative abundance of native and feral predators, respectively. Notably, there is substantial connectivity between many of these factors. Nature can be complex.

There are many examples of synergistic interactions between threats in Outback ecology, but perhaps the most notable are between fire and various factors such as invasive grasses, numbers of stock or feral animals and climate change. Examples of some of these interactions are discussed below.

Fire both contributes and responds to climate change. Northern savanna fires release about 3% of Australia's total annual accountable emissions (non-CO2, methane and nitrous oxide only) (Cook *et al.* 2005; Williams *et al.* 2005; Richards *et al.* 2012), thereby contributing to the drivers of climate change. The incidence, extent, intensity and impacts of fire will increase in most Outback areas – and in almost all parts of Australia – because of climate change and also because of one of its drivers, increased atmospheric CO2 levels. The latter will increase the productivity of plants, particularly grasses, across most Outback areas, thereby increasing vegetation biomass and fuel for fires. Some of these impacts are already apparent. For example, there has been a substantial increase over the last few decades in average and maximum annual fire-danger indices in Alice Springs and these are projected to increase (Williams *et al.* 2009b). The number of very hot days will rise across much of the Outback, increasing vegetation desiccation, and thus the likelihood of fire ignition and spread. More very hot days will increase the incidence of megafires – those that overwhelm the capacity of managers to respond.

Land use also affects fire regimes. Most notably the incidence and extent of fire are generally less on pastoral lands (Franklin *et al.* 2008; Woinarski *et al.* 2013) because many pastoralists seek to exclude or suppress fire more than most other Outback landowners and because grazing by livestock reduces

The threatened Partridge Pigeon lives in the monsoon tropics of the Northern Territory and Western Australia's Kimberley region. Nesting on the ground, it may be substantially affected by changed patterns of fire, feral cats and over-grazing.

Figure 51

Threats, Habitats and Resources for the Partridge Pigeon: An Ecological Wiring Diagram

Ecological wiring diagram shows connections between threats, environmental conditions and pressures

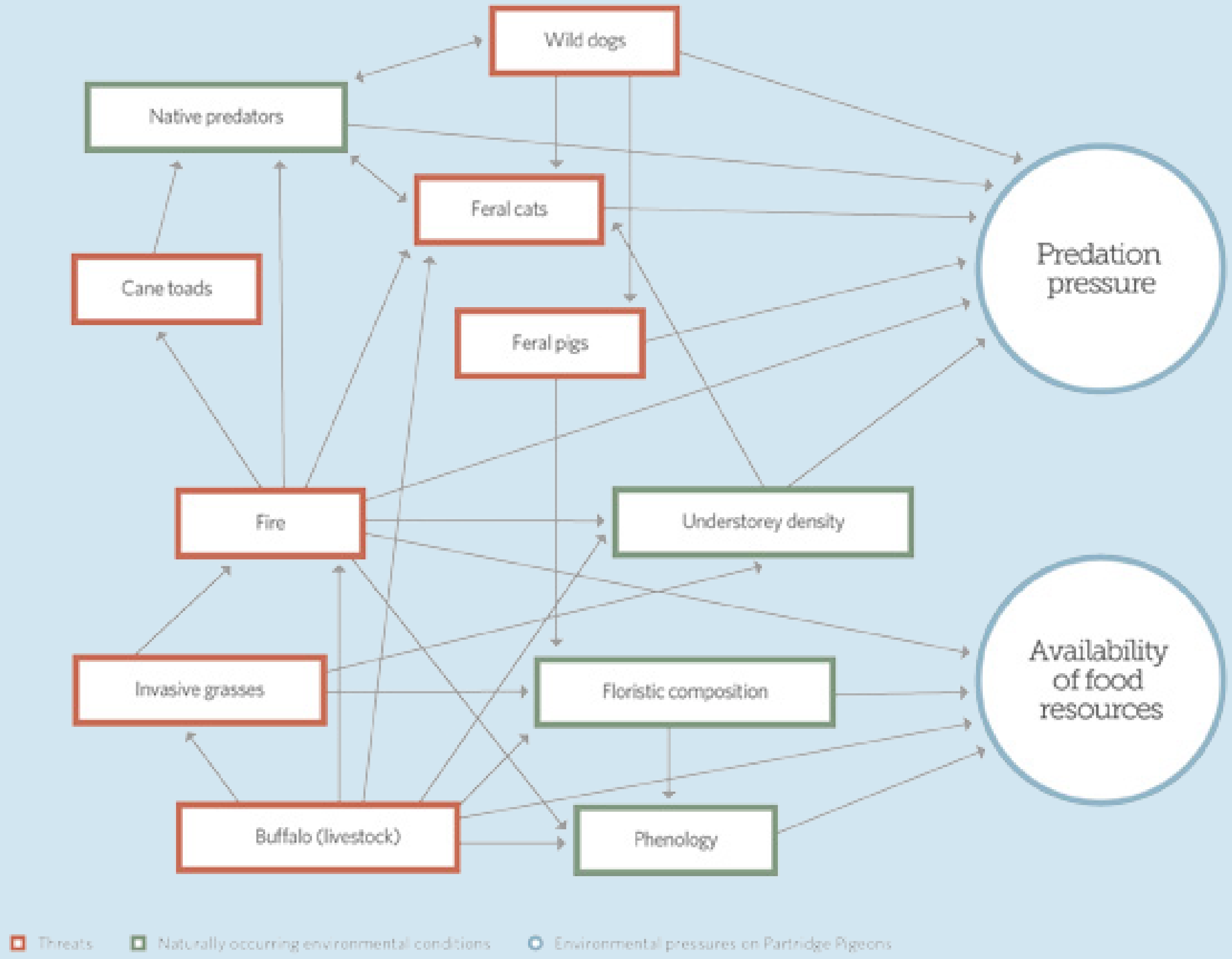


Figure design by The Pew Charitable Trusts

the fuel for fire. Some have argued that this both benefits biodiversity and reduces greenhouse gas emissions, and/or that high stocking rates act as a disturbance agent of greater benefit to the environment than fire (Savory 1988; Outcomes Australia Soils for Life Program 2012). However, comparative cross-tenure studies indicate there is no such net biodiversity benefit of pastoral activity in the Australian Outback (Woinarski *et al.* 2013), probably because pastoralism is directly detrimental to some components of biodiversity. Furthermore, less-frequent fires due to pastoralism may also be detrimental to some native species. For example, many of the earliest incidences of decline in Outback bird communities were reported soon after the initial establishment of pastoralism. This was probably due in part to loss of the pre-pastoral fire regimes (Woinarski and Catterall 2004; Franklin *et al*. 2005). The argument that intensifying pastoral production will reduce fire-driven greenhouse gas emissions is also not straightforward because emissions vary substantially with fire intensity and because the substantial methane emissions from livestock may be at least as detrimental overall as emissions from fire.

7.6. Impediments to threat management

It is a conundrum that some of the factors that contribute to the global environmental significance of the Outback also serve to subvert that value. They render the impact and spread of threats more likely and the management of those threats more challenging. A series of distinctive ecological and socio-economic factors, and more generic factors, constrain the effective management of threats in the Outback:

Outback characteristics mean that threats readily become pervasive. The Outback's expanse, its relatively flat terrain and its lack of marked environmental disjunctions mean that any threatening factor, once introduced into the system, is likely to spread widely.

The patchy nature of Outback environments renders them particularly susceptible to threats. A key feature of Outback ecology – the dependence of large ecological systems on small, embedded resource-rich patches and refugia – is readily altered by threats such as feral animals that use and degrade those resource-rich patches.

Capability is limited relative to the extent of the problem. The Outback's typically small human population size, low land values, limited regional economies and constrained accessibility mean that few resources are available to intensively or extensively manage threats. In the Outback, many governance bodies – whose counterparts in more settled regions can readily coordinate and implement threat management – are insecure and have limited capacity and capability.

Threat management requires long-term strategic response, but resourcing is short-term and insecure. Most Outback threats are now deeply entrenched and may take many decades of dedicated management to control. However, most resourcing available for threat management is short-term (typically 1–3 years) and natural resource management funding programs typically suffer from shifts in paradigm and political priorities at frequent intervals.

There is little coordination in problem definition and resolution across Outback jurisdictions and tenures. Outback environments are dissected by political and tenure boundaries and it is difficult to develop and retain effective and long-term coordination for threat management across jurisdictions or landholder groups. This is particularly so where landholders on some tenures see a factor – such as foreign pasture grasses – as a benefit and others see it as a threat.

Threats to biodiversity are not broadly known. There is a general lack of awareness of the detrimental environmental impacts of many threats. In part, this is because there is so little – and no coordinated – biodiversity monitoring and reporting in the Outback (McAlpine *et al.* 2014). In part, it is because many Outback species are inconspicuous and have low public profiles and their decline therefore goes largely unnoticed. In part, it is because some threats, such as fire and livestock, are widely perceived as a natural, proper or unavoidable component of the Outback.

The legal framework is inadequate for the problem. Australian environmental laws work better for acute and local issues, such as assessing the environmental risk of a mine or housing estate, than for broad-scale and insidious issues, such as managing fire and feral animals. Some of the major threats to environmental values in the Outback are addressed in national or state/territory legislation, mostly through threat-abatement plans for listed key threatening processes under the national *Environment Protection and Biodiversity Conservation Act 1999*. But such abatement plans have little obligation or resourcing, and many key threats are not listed. In some jurisdictions, landholders have regulatory obligations to control particular threats, but these are rarely enforced.

7.7. Framework for response

If we are to maintain the nature of the Outback, then we need to control or manage threats to its values. In the following paragraphs, we note some examples of success in managing threats and features that have helped to achieve that success.

(i) Environmental values can respond markedly to the control of threats. There are many examples in the Outback demonstrating that biodiversity objectives can be realised. For example, a program for the control of feral donkeys in the Victoria River District in northern Australia produced substantial benefits: 'The recovery … within five years [of culling 28,000 donkeys] was amazing yet because of the donkeys it had previously been wasteland' (Letts *et al.* 1979). Following removal of all livestock from large areas of a pastoral property in the Kimberley, the abundance of native mammals increased markedly within three years (Legge *et al.* 2011).

(ii) Threat management can deliver multiple benefits. An example is that of the West Arnhem Land Fire Abatement (WALFA) program established to reduce the incidence of extensive uncontrolled fires by replacing it with a regime of a more considered patchwork of low-intensity fires (see Box 16).

(iii) It is feasible to coordinate actions across landholder groups to collectively abate regional-scale threats. For example, the Ecofire program operates over four million hectares in the Kimberley, to mitigate fire regimes. Collectively, state conservation agencies, pastoralists, Indigenous groups and conservation NGOs recognised detriment to their interests from the previous regime of extensive uncontrolled fire, and collaborated on a multi-year program that has successfully reduced the incidence and extent of uncontrolled fire (Legge and Fleming 2012).

(iv) It is feasible to coordinate actions to effectively abate major threats across multiple regions. The most notable recent example is the three-year program to reduce the population and impacts of feral camels across most of their 3.3 million km^2 range. This collaborative program – involving the Australian, state and territory governments; Indigenous agencies; natural resource management organisations; research groups; pastoral organisations; commercial operators and conservation groups – succeeded in reducing camel populations at key sites for biodiversity, cultural, tourist and pastoral values (Ninti One 2013).

(v) Most problems are solvable: sustained intensive actions can succeed against apparently near-unbeatable threats, to deliver impressive biodiversity benefits. Happily, there are several such examples in the Outback. In Kakadu National Park, an unrelenting program of surveillance and control has succeeded in keeping the floodplains free of the invasive shrub *Mimosa pigra*, which would otherwise rapidly transform this wildlife-rich habitat. Similar success has been achieved with keeping Gamba Grass out of Kakadu's lowland woodlands.

On the lower rainfall margins of the monsoon tropics, research indicates that cane toads can be excluded or eliminated from extensive landscapes if they can be kept away from the typically isolated water sources by perimeter fencing (Tingley *et al.* 2013). Such a strategy could greatly reduce the likelihood of toads colonising the Pilbara region.

Feral cats are notoriously difficult to control. However, at an increasing number of sites across the Outback, predator-proof fencing has demonstrated that native mammals may respond rapidly when predators are controlled. The high costs and intensive maintenance requirements of

Central Land Council rangers help the Council's camel management officer with a muster of feral camels at Undurana Camel Farm, 300 kilometres west of Alice Springs in the Northern Territory. The camels are being farmed and sold in Australia and overseas. The Indigenous-run farm is sponsored by Santos, which operates nearby oil and gas fields.

such fencing have limited this management to relatively small areas, but a recent program of mammal reintroduction at Lorna Glen (Fortescue Marsh area) in the Pilbara has demonstrated that comparable and broader-scale benefits may be obtained, in at least some Outback areas, by intensive baiting for cats. Fox control has been more tractable and large-scale baiting programs have been established at a range of sites, in Outback – for example, the Bounceback program in the Flinders Ranges – and non-Outback regions, with substantial biodiversity benefits.

(vi) Key refuge areas for biodiversity can be identified and afforded extra protection. The most important such sites in Australia are offshore islands. Many of Australia's largest islands are in the Outback and some offer protection to their biodiversity from threats extensive on the mainland. However, the protection offered by islands cannot be assumed (Woinarski *et al.* 2011b). Instead it may require strategic and well-considered biosecurity measures. Examples in the Outback include quarantine programs designed to stop the arrival of cane toads to Groote Eylandt (coordinated by the Anindilyakwa Land Council) and the Tiwi Islands (Tiwi Land Council). Some species threatened throughout their mainland ranges have been translocated to islands free from these threats, preventing extinctions in some cases. Examples of successful activities have included moving Northern Quolls to toad-free islands off Arnhem Land and Golden Bandicoots to two islands off Arnhem Land to increase their Northern Territory range from one island to three islands (Rankmore *et al.* 2008; Palmer 2009).

(vii) In some circumstances, effective partnerships with industry can underpin resource-intensive and long-term threat management actions. In the Outback, such cases have typically involved environmental offsets from major development projects. The Lorna Glen restoration program has reintroduced threatened mammals to mainland areas subjected to effective control of predators, stock and fire, as one offset from the Gorgon gas project on Barrow Island. Likewise, the Arid Recovery mammal reintroduction project is associated with the Olympic Dam mine at Roxby Downs. The Western Arnhem Land Fire Abatement program is funded in part through emission trading by ConocoPhillips (Whitehead *et al.* 2009) (see Spotlight 10).

(vii) Threat management activity can be prioritised to ensure that funding is allocated to deliver the most substantial benefits. In all Outback regions, there is a bewildering array of threats affecting, to varying degrees, a wide range of conservation and other values. However, it is now increasingly possible to objectively prioritise management of these threats to deliver the most substantial return on investment. Notable recent examples include case studies in the Pilbara and Kimberley (see Insight 7) (Carwardine *et al.* 2011).

(ix) There are now robust biosecurity protocols for risk assessment for weeds and pests. Such risk assessment can effectively prioritise actions limiting the entry of new pests and weeds and can be used as a rational basis for reconciling competing perspectives, notably for cases such as invasive pasture grasses (Setterfield *et al*. 2010).

(x) Threat management is increasingly undertaken in an auditable manner, and reporting describes environmental outcomes rather than simply management activity and inputs. Much management directed towards threats in the Australian Outback is now undertaken in a manner that acknowledges financial obligations to report to investors. This is particularly the case for conservation NGOs that manage lands for conservation and must satisfy their supporters they are achieving tangible results. Such organisations have well-developed monitoring and reporting systems to document the results of their threat management actions (Radford *et al.* 2012). Such monitoring and reporting is increasingly recognised as part of business for government conservation agencies (Radford *et al*. 2011), Indigenous land management groups (Fitzsimons *et al*. 2012), and offset-supported land management programs (Russell-Smith *et al.* 2009a; Russell-Smith *et al.* 2013).

Several features can be distilled from these examples of successful threat management for the Outback. Any program or strategy for the Outback must be collaborative – it needs to involve substantial participation from a diverse set of stakeholders and others. Where values conflict, a pathway to resolution must be identified. The ecology and economy of much of the Outback often works on decadal time scales, and threat management in the Outback is not generally readily resolvable in periods of a few years, so there is a need to develop strategic and long-term goals. Within such established goals, there may still be a wide choice of management actions, and – given finite resources – it is important to prioritise responses, actions and areas that most effectively contribute to realisation of the long-term goals. It is also important to measure and report regularly on the outcomes of such management. For some threats, there are no known effective control options, so there may be need to undertake research to deliver such knowledge. There is limited capability to implement some management actions, so enhancing capability or capacity in some management agencies and personnel is needed.

Importantly, the threat environment in the Outback is not static and new threats continue to appear. The most cost-effective way of dealing with new pest and weed threats is generally to prevent their arrival or establishment through effective biosecurity systems. In the Outback this applies also to existing threats becoming established in key refuge areas and other important areas.

Spotlight 10 **The West Arnhem Land Fire Abatement project**

The 'stone country' of western Arnhem Land in the monsoon tropics of northern Australia is an important centre of endemism for plants and animals (Woinarski *et al.* 2006; Woinarski *et al.* 2009). It encompasses an area of about 34,000 km^2 of extremely rugged terrain, with very little infrastructure and fewer than 100 permanent residents. It is Aboriginal land, with about 30% managed within Kakadu National Park and an additional 40% managed within the more recently established Warddeken Indigenous Area. This country contains some of the most vibrant, numerous and significant Aboriginal art sites in Australia and was carefully managed by Aboriginal clan groups for thousands of years. However, this management was interrupted when the area was largely depopulated over the course of the 20th century (Cooke 2009).

As a consequence of the broad-scale loss of Aboriginal custodians, fire regimes in the stone country became uncontrolled and by the late 20th century were characterised by frequent, extensive, intense fires in the late dry season, that were causing retreat of rainforest environments, decline in many of the area's endemic fire-sensitive plants and animals, and damage to art sites. This environmental and cultural degradation prompted the establishment in 1997 of a major collaborative program – the *West Arnhem Land Fire Abatement project (WALFA)* – across Aboriginal landowner groups, the relevant Aboriginal Land Council and government agencies. This program aimed to restore intensive management and rein in uncontrolled and destructive fires through the application of a strategic and tightly monitored program of imposed early dry-season fires.

Using satellite-based calculations of area burnt annually, fuel loads, and emissions from fires of different intensities, scientists could calculate the total greenhouse gas emissions over the WALFA area under a range of fire regimes and demonstrate very substantial reductions when fires were managed through pre-emptive burning, relative to the previous uncontrolled regime. Coincidentally, a major natural gas processing plant was being developed in Darwin by a subsidiary of the transnational energy company ConocoPhillips, which committed to offsetting part of the greenhouse gas emissions – and local loss of parts of a rainforest patch – arising from their newly established infrastructure. As part of its licence to operate, from 2006 ConocoPhilips agreed to a 17-year, A$22 million agreement for the WALFA program to manage fire to a level that reduced the emission of carbon dioxide equivalent gases by 100,000 tonnes per year. (Whitehead *et al.* 2009).

The program has been extremely successful. In 1995–2004, the decade before the agreement, the average area burnt per year in the WALFA region was 36%, predominantly due to late dry-season fires (Russell-Smith *et al.* 2013). WALFA has shifted the regime to one instead dominated by cooler and patchier early dry- season fires, resulting in an average annual saving in emissions of about 117,000 tonnes of carbon dioxide equivalent gases (Murphy *et al.* 2009). Net carbon savings are substantially more than this, because less fire, or cooler fire, results in substantially increased sequestration (Richards *et al.* 2012).

The program is also improving prospects for the area's biodiversity. It has also helped foster about 30 Indigenous ranger jobs, catalysed greatly increased organisation capacity and capability in local groups, and provided substantial educational and health benefits (Whitehead *et al.* 2009).

Traditional indigenous fire management involves lighting lower-intensity fires that benefit hunting and reduce the likelihood of larger-scale and more destructive wildfires. Indigenous ranger Eddie Phillips conducts a burn in savanna woodland near Kabulwarnamyo in Arnhem Land, as part of an early dry season fire management program.

Insight 7

Prioritising threat management

A patient presents at a casualty ward of a small hospital. She has multiple problems. On examination, the doctor concludes that some of these be easily dealt with but are of little consequence anyway, some may be serious but can't be readily resolved, but another life-threatening problem can be addressed with substantial but tractable resources. Many other patients are also present in the ward, with similar or different sets of concerns. How does the hospital choose to prioritise? This problem has direct parallels with that of managing Outback biodiversity, particularly threatened plants and animals. There are many threatening factors, and consequently many threatened species, and the resources to manage these are finite.

There are clear lessons from the health system. Prevention is better than cure, so it is most efficient and economical to pre-empt threats through good biosecurity systems and thorough risk assessment of factors that may affect environmental values. Much of the health budget is spent on research to understand how disease works and to seek cures, and on monitoring to report on the incidence of disease and efficacy of treatment, and to establish regular check-ups for early detection of disease. Comparable research and monitoring is necessary, and ultimately cost-effective, for threatened species management. Education and community awareness helps, as does philanthropy and corporate investment to increase the available resourcing. Coordination – for example in vaccination programs – is important: programs operating in only some segments of the population or some regions may ultimately be futile if the problem is not addressed across its range. And some problems may be impossible or unreasonably expensive to try to fix. In such cases, palliative care – comparable to survival only in zoos or botanical gardens – may be the only available option.

Faced with the 'agony of choice', there are optimisation protocols that can help conservation managers to select those management actions that can deliver the most substantial conservation benefits. In one recent Outback example, for the Kimberley region, Carwardine *et al.* (2011) collated expert opinion on the costs and feasibility of a wide range of potential threat management actions and the likelihood of extinction of a large set of vertebrate animal species under current management regimes, and under each of the set of management actions, and then were able to select the most efficient set of management actions that could maintain the most species. They concluded that without management of current threats, 45 animal species would be 'functionally lost' (i.e. likely to become extinct) in the Kimberley in the next 20 years; that all species would be likely to be secured with a strategy that included an initial and immediate investment of A$95 million followed by an ongoing annual investment of A$40 million; and that the most cost-effective management actions were to reduce the impacts of feral cats, to manage fire and to reduce the impacts of feral herbivores. Weed control was ranked of lower benefit because as yet the weed problems in the Kimberley are not 'alarming' and it was difficult to quantify the benefits of keeping out potential new weeds. Weed management would probably rate more highly for plant conservation, but this particular study did not consider threatened plants. The study also concluded that the current rate of investment (about A$20 million per year) would be insufficient to avoid the likely functional loss of 31 wildlife species from the region over the next 20 years.

The advice to prioritise the management of feral predators, fire and feral stock is not new or surprising, but this study is important in quantifying the risks of inaction or of inadequate or suboptimal actions, and of quantifying the investment required to maintain a region's biodiversity. The conclusion is sobering but realistic: current management resourcing will not be sufficient to stave off extinctions. The extra resourcing required to maintain Outback biodiversity is formidable, but not unachievable.

> The conclusion is sobering but realistic: current management resourcing will not be sufficient to stave off extinctions.

Desmond Daly (left) and Jeff Long are members of the Fish River Rangers, who manage the 178,000-hectare Fish River Station in the Northern Territory for conservation and cultural heritage. The former cattle property was purchased through a ground-breaking partnership of the Indigenous Land Corporation, The Nature Conservancy, The Pew Charitable Trusts and the Australian Government.

8. The changing Outback

Much of the Outback seems timeless and immutable. This perception, or misperception, may apply not only to the natural landscape but also to the Outback's people. There are still places in the Outback where Aboriginal people live largely traditional lives, living off and nurturing the land, honouring the same ceremonies, speaking the old languages. There are dusty and creased stockmen, with Akubra, horse and whip, who mirror their grandfathers. There are Outback towns and pastoral stations that are little or no different in looks and character than they were a hundred years ago.

> The Outback is now going through extraordinary change, resulting variously from local, national and global factors.

But this is partly a façade. The Outback is now going through extraordinary change, resulting variously from local, national and global factors. There are many threads, not necessarily concordant, in this transition.

The Outback is becoming increasingly subject to a diverse range of factors that are bringing welcome, unwelcome or uncertain change to its society, economy and environments. To a large extent, the future of the Outback, and the extent to which that future Outback retains its special values, will be determined by the manner in which these influences are managed and guided.

Here, we consider recent changes in the social and economic fabric of the Outback and the way it is being managed. A key conclusion is that, although Outback communities' resource use and governance are rapidly changing, there still is no clear pathway to that change or a shared sense of the destination.

8.1. Broad trends for change in landownership and use

For well over a century, the economic development of the Outback has been 'necessarily left in the main to the pastoralist and the miner' (Gregory 1906). However, the growing influence of Indigenous and conservation landholders, and some increased tourism and other diversification in more recent times can be seen as signalling a marked transition in Australia's rangelands and a reduction in pastoral dominance (Holmes 2002).

One of the most profound of these factors is the rapid recent increase in the extent of lands owned and managed by Aboriginal people across the Outback (Table 7). This has been driven in large part by the High Court's landmark Mabo decision in 1992 recognising native title in Australia and the Wik decision in 1996 recognising that pastoral leasehold did not necessarily extinguish native title, with consequential legal accommodation. Furthermore, there has also been a program of acquisition, particularly of pastoral properties, by the Indigenous Land Corporation and by various negotiated arrangements with some governments for the recognition of Indigenous ownership of formerly established conservation reserves.

Obviously, Aboriginal people have a long held connection and claim to the Outback lands, but these recent changes have given substantial legal recognition and practical effect to this affiliation. Although the momentum of changes in Indigenous rights to, and ownership of, land in the Outback have been dramatic since the 1990s, the process itself may be slow, with resolution of native title claims typically taking many years. Of 441 claims awaiting resolution at June 2012, 49% were lodged more than 10 years earlier, and 18% had been lodged for 5 to 10 years (National Native Title Tribunal 2012). The Outback land tenure configuration is still highly dynamic and may take decades to fully resolve.

Outback lands acquired by Indigenous groups through native title or by purchase have been used for various purposes. In many cases, previous pastoral activity has been retained, in part in compliance with obligations under the pastoral lands legislation of the Outback states and Northern Territory. In some cases, native title has been negotiated over lands as part of a package that has facilitated the establishment of major mining ventures. In cases of pre-existing conservation reserves, that function has been maintained, in many cases through a variety of co-management systems with government or non-government conservation agencies. But the most substantial change in land use across the Outback has been the establishment of Indigenous Protected Areas on Aboriginal lands (see next section).

Mining has had a long history in the Outback, but the scale of mining and gas ventures has escalated substantially in some areas since the 1970s, and these ventures now dominate the social and economic fabric in some regions. In its wake, parts of the Outback, most notably the Pilbara but also many other more localised sites, have become industrial hubs, with the creation of new towns, redevelopment of old towns, major expansion of transport routes and other infrastructure, unprecedented demand for water resources, major landscape modification, and marked change in social and economic features.

Table 7

A Chronology of Some Landmark Legislation and Policy Relating to Indigenous Land Management Issues in the Outbackt

Initiative	Date	Description
Northern Territory Cattle Industry Award	1968	Minimum wage introduced – an unintended consequence was a wave of Aboriginal people forced off cattle properties
Aboriginal Land Rights Act (Northern Territory)	1976	Australian Government legally recognises the Aboriginal system of landownership and put into law the concept of inalienable land title
Community Development and Employment Program	1977	A program established to develop skills and to improve capacity, work readiness and employability of Indigenous people and link with local priorities (phased out in 2012)
Joint management established for national parks	1981	The first establishment of joint management (a sharing of management responsibilities between Aboriginal owners or claimants and government conservation agencies) for a conservation reserve, Gurig National Park
High Court's Mabo judgment	1992	Refutation of *terra nullius*, that the land was unowned prior to European settlement
Native Title Act	1993	Legislation that sets out the processes for the determination of native title rights and dealings on native title land (response to the 1992 Mabo judgment)
Indigenous ranger program	1995	Establishment of the first Indigenous ranger program
High Court's Wik judgement	1996	Recognition that pastoral use did not necessarily extinguish native title rights
Indigenous Protected Area program	1997	First IPA established
Working on Country	2007	Part of the Caring for our Country initiative, which builds on Indigenous knowledge of protecting and managing land and sea country
Northern Territory Emergency Response	2007	A set of measures designed to protect children, make communities safe and build a better future for people living in Indigenous communities in the Northern Territory
High Court's Blue Mud Bay decision	2008	Recognition of traditional owners' property rights in tidal waters

Note: This table is based on Gorman and Vemuri 2012, which focuses particularly on Northern Territory issues.

Table design by The Pew Charitable Trusts

One of many dedicated mining towns dotting the Outback, Leigh Creek in South Australia sits on the edge of the desert, west of the Flinders Ranges. Coal is sent from the nearby mine, on the longest coal train in Australia, to power stations in Port Augusta.

In caricature, the Outback has become a two-paced economy, with relatively stagnant or subdued economies in regions associated with long-established activities and spurts of major growth and economic activity in other regions associated with gas and mineral production.

> The scale of mining and gas ventures has escalated substantially in some areas since the 1970s, and these ventures now dominate the social and economic fabric in some regions.

Intensive horticulture, typically supported by river impoundment or water extraction, has expanded fitfully in some Outback areas, but it is now substantially established in the Ord (east Kimberley), the Carnarvon area (mid-coastal Western Australia) and the Katherine–Darwin area (of the Top End). In recent decades, the scale of these developments has increased substantially, and there are ongoing interests in the prospects for expanded horticultural development generally, with particular focus on the Fitzroy system in the west Kimberley, Keep system in the western Top End, Ti Tree in central Australia, around major river systems in the Queensland Gulf area and in river systems of inland western Queensland. Such interest prompted a recent appraisal of the land and water resources of northern Australia (Northern Australia Land and Water Taskforce 2009) and has been a major stimulus for a current Joint Select Committee Inquiry of the Australian Government that aims to identify resource potential and the institutional and economic mechanisms that can be used to more effectively realise that potential.

Since the 1990s, the pastoral lease system has been subjected to reviews in most Outback jurisdictions, with broad concerns relating to tenure security, Indigenous interests, diversification options, environmental responsibilities and options, regulations relating to intensification of pastoral use, and the status and future of marginal and nonviable properties. These review processes may achieve some fundamental changes in land use across those vast areas of the Outback that have long been managed with a narrow focus on producing livestock.

The continuing changes in Outback land use and tenure are not accidental. They reflect the long demonstration of unsustainability or unprofitability of pastoralism in much of the Outback and the more recent recognition of Indigenous rights and the demonstration of Indigenous land management as an important and productive land use. They also reflect that our society more broadly has changing perceptions of the land and its constraints, and our responsibility to it. Steve Morton and Barney Foran described these changes in the environment and society over the century since the landmark 1894 Horn Expedition to central Australia:

'Land allocation reflects and expresses society's dominant beliefs about values inherent in the country. At the time of the Horn Expedition, Aboriginal values were either not recognised by white people or were held to be without significance – pastoralism and mining were the only land uses perceived to be possible and legitimate, and indeed it was believed that they constituted a natural and necessary pathway for civilising the land. During the last few decades of the twentieth century two other land uses have gradually come into active play. One comprises a combination of conservation and tourism, and the other is Aboriginal use' (Morton and Foran 1996).

In the few years since this assessment, the pace of change has quickened and there has been significant convergence between those two 'new' directions—of conservation and Aboriginal use.

8.2. The changing nature and role of conservation reserves

The purpose, extent, management and governance of conservation reserves in the Outback are changing. The case for conservation reserves there is longstanding and can be traced back at least to Hedley Finlayson in the 1940s:

'From the point of view of the naturalist, the length to which the process of change will ultimately go is not to be measured by head of population per square mile, nor even by the numbers of stock which the country will carry, but rather by the presence or absence of sanctuaries where conditions are such that stock and all the disturbing factors of settlement cannot operate. One of the tragedies of this country is that it is almost destitute of such natural sanctuaries' (Finlayson 1945).

Perhaps a dozen native mammal species may have been saved from extinction had there been a timely and effective response to Finlayson's entreaties. Instead, the development of a conservation reserve system in the Outback was to take decades, with slow and fitful progress.

There were some exceptions: a notable example was the declaration of Cobourg Peninsula flora and fauna reserve in the Top End of the Northern Territory in 1924, but this was particularly unusual and an almost entirely nominal status. For the Northern Territory, but probably typical of Outback areas generally, the first legislation relating to national parks was established in 1955, but reserves added in the following decade were almost all very small sites of recreational or tourism value or of significance for settler history (Woinarski 2005). Initially, management guidelines were largely restricted to the cosmetic: 'invariably it is the policy of the Board to erect an entrance archway of natural stone pillars, surmounted by wrought iron title, with one of the pillars carrying a bronze plaque' (Rose 1969). There was also a contrasting approach, mostly developed from the 1960s, of unilateral declaration of larger 'wildlife sanctuaries' in ostensibly empty and economically valueless remote lands – for example, the Tanami Desert Wildlife Sanctuary. These were largely unmanaged, and involved little or no consultation or co-management with Aboriginal landholders. One notable long-established Outback conservation reserve is Uluṟu–Kata Tjuṯa (originally Ayers Rock–Mount Olga), dedicated in 1958.

From the 1960s and 1970s, and in concert with international standards, there developed across Australia generally an impetus for a more systematic and comprehensive conservation reserve system that included representation of all major environments. But this has been somewhat grudgingly accepted, with parks often being restricted to lands otherwise unwanted for any enterprise that had a chance of profitable use. In some cases, it amounted to a box-ticking exercise without a sound ecological basis. For example, a CSIRO report to the Australian Government, 'Principles of a balanced land-use policy for Australia' (Hallsworth *et al.* 1976), considered that 'it seems likely that it will be necessary to have wildlife reserves of not less than 200 hectares each at several locations in each of the major vegetation associations'. We know now that such a system of tiny and fragmented parks would dismally fail to protect most species in the long term.

A set of high-level inquiries regarding land use and ownership issues (relating to uranium mining, tourism, conservation, Aboriginal land ownership and relationships between the Australian and Northern Territory governments) in the Kakadu area in the 1970s provided a pivotal and carefully considered approach to the legitimacy of conservation reserves and the manner in which potentially competing interests may be accommodated, reconciled or prioritised (Aboriginal Land Rights Commission 1973, 1974; Ranger Uranium Environmental Inquiry 1976, 1977). These landmark decisions helped recognise the international value of at least some areas of the Outback for biodiversity and Indigenous culture, the desirability or need for conservation reserves that were much larger than previously allocated, and the vital role of Aboriginal people in the ownership and management of conservation reserves. Large reserves are increasingly recognised to be the cornerstone for biodiversity conservation (Parr *et al.* 2009), especially in the era of climate change (Hodgson *et al.* 2009).

The Ranger uranium mine in the Alligator Rivers Region of the Northern Territory occurs as an enclave within the iconic Kakadu National Park. The proclamation of the national park was one outcome of recommendations from the Ranger Uranium Environmental Inquiry (1975–77). The mine was commissioned in 1981, the same year the national park was inscribed on the World Heritage list.

From the late 1970s, there has been a substantial increase in the number and size of conservation reserves in the Outback: for example, the first components of Kakadu National Park were established in 1979. In some regions, such as the Kimberley (Burbidge *et al*. 1991), these newly established conservation reserves were sited carefully to achieve substantial progress towards a comprehensive, adequate and representative reserve system. However, most progress was achieved in remote lands with marginal or no economically productive potential, and environments of high pastoral productivity and profitability were largely avoided, either because pastoral representative groups had more political power than conservation interests, or simply because prices for purchasing pastoral leases were seen to be prohibitively expensive for the acquisition of conservation reserves (Woinarski *et al.* 1996a; Woinarski *et al*. 1996b).

However, ecological and evolutionary processes in the Outback usually work at scales far larger than the size of individual conservation reserves. While national parks in the Outback have been demonstrated to deliver better conservation outcomes than similar surrounding lands (Woinarski *et al.* 2013), even the largest Outback conservation reserves have now been found to be inadequate for the maintenance of some ecological and evolutionary processes and for highly dispersive species (Woinarski *et al.* 1992; Woinarski *et al.* 2010).

> Large reserves are increasingly recognised to be the cornerstone for biodiversity conservation. However, ecological and evolutionary processes in the Outback usually work at scales far larger than the size of individual conservation reserves.

A striking example of this inadequacy is the recent evidence of a marked decline in the native mammal fauna of the 20,000 km^2 Kakadu National Park, one of the Outback's premier and best-resourced conservation reserves (Woinarski *et al*. 2001; Woinarski *et al.* 2010). In many cases, Outback conservation reserves have infestations of weeds and pests (Bradshaw *et al*. 2007) and suffer fire regimes that are detrimental to biodiversity. In many cases, the available resources are inadequate to reduce these threats to acceptable levels (Salmon and Gerritsen 2013). Often, the primary conservation purpose of the reserve is not being met. This failure is for various reasons – because the biodiversity objectives have not been well defined, because management is focused primarily on tourism, because resources are inadequate to deal with threats to biodiversity and/or because there is little or no accountability of managers for failure to meet biodiversity objectives (Parr *et al.* 2009).

The challenge is to further improve the effectiveness of conservation reserves by paying more attention to the health of the surrounding landscape as well. The demonstration of large areas required to maintain ecological processes, and the extensive and largely unmodified Outback nature, has rendered as a largely inappropriate model the traditional concept of national parks as a set of disconnected representative isolates surrounded by mainly modified lands of low value for conservation. Land use in the Outback is not so binary, of marked contrasts between unproductive lands devoted to conservation surrounded by productive lands managed in a manner unsympathetic to conservation. There are two major consequences of this recognition: (i) that conservation reserves should seek to transform from a representative set of isolates to a linked network operating across extensive landscapes, and (ii) that complementarily there is opportunity and need to maintain the significant conservation values on lands that are not formally part of the conservation reserve network. There have been some significant advances in the landscape-scale (indeed, continental scale) linkages of Outback conservation reserves, notably in some Outback areas of South Australia, Western Australia (Bradby 2012) and the Northern Territory (Bridges 2012).

Worldwide, the traditional establishment, governance and management approach for conservation reserves has also been subjected to substantial change over recent decades, and this trend is also apparent in the Outback. While government conservation reserves remain a core part of reserve systems around the world – and there is an opportunity for and benefit in these continuing to increase and expand – a variety of new conservation land tenures are becoming more common. The potential for such non-government reserves, including privately owned and Indigenous reserves, to make an effective contribution to a greater whole was formally recognised by the IUCN World Commission on Protected Areas in 2008 (Dudley 2008).

In the Outback, there have been two main advances. Firstly, a rapid increase in the number and extent of conservation reserves run by non-government conservation organisations. Secondly, a rapid increase in the number and extent of Indigenous Protected Areas and of recognition of Indigenous ownership and co-management of existing national parks. Both trajectories represent a response to, or have driven, a reduced role of government agencies, or direct government resourcing, for conservation land management. They also recognise that traditional government-controlled national parks will not of themselves be adequate to maintain biodiversity.

In the Outback, two non-government conservation organisations, the Australian Wildlife Conservancy (AWC) and Bush Heritage Australia, have acquired – or have been contracted by other landowners to manage – substantial and significant lands as conservation reserves. The objective of AWC is to manage lands specifically and primarily for biodiversity conservation, particularly for threatened mammal species. The AWC now manages 23 sanctuaries for conservation, comprising a total area of about three million hectares, mostly in the Outback. Bush Heritage owns and manages 35 reserves with a combined area of about one million hectares.

The growth in this privately managed conservation estate has been spectacular and important, but the recent (and complementary) growth in the number and total extent of Indigenous-owned and -managed conservation reserves has been even more remarkable. Joint management, in the form of collaborations between Indigenous owners and government conservation agencies, of some Outback national parks has been in place since the 1970s. Notable early examples are those of Garig Gunak Barlu (Cobourg Peninsula) and Kakadu national parks. Indeed, the underlying principle was firmly entrenched by the 'Woodward Commission' (Aboriginal Land Rights Commission 1974) that joint management would 'reconcile Aboriginal interests with those of conservation'. Across the Outback, one strand of this initiative has involved recognition of ownership and formal 'handback' of many already established national parks. But more expansively, it has also included the dedication of many new, and large, areas for conservation in the form of IPAs.

In part, this expansion itself has been prompted by a rapid increase in the extent of lands now legally recognised to be Aboriginal-owned. The first such IPA, Nantawarrina, in the Flinders and Gammon Ranges of South Australia, was established in 1997–98. The program has expanded rapidly: as at June 2014, it included more than 60 IPAs, with a combined area of more than 50,000 km^2, about 40% of the total Australian conservation reserve system (Figure 52). Most, and all of the very large, IPAs are in the Outback and their total area now comprises almost 10% of Outback land (Table 8).

> There is now substantial evidence that IPAs and ranger groups deliver not only benefits to biodiversity but also significant health, employment, education and economic benefits to the typically severely disadvantaged remote communities in which they are based.

Table 8

Growth of the IPA Program in the Australian Outback

Year	Cumulative land area (km^2)	Cumulative number of Outback IPAs
1998	584	1
1999	5,226	2
2000	32,489	4
2001	33,511	6
2002	141,670	9
2003	141,670	9
2004	141,670	9
2005	141,670	9
2006	149,487	12
2007	207,082	14
2008	208,881	15
2009	232,508	19
2010	242,226	22
2011	261,727	25
2012	364,600	26
2013	475,550	34
2014	500,347	35

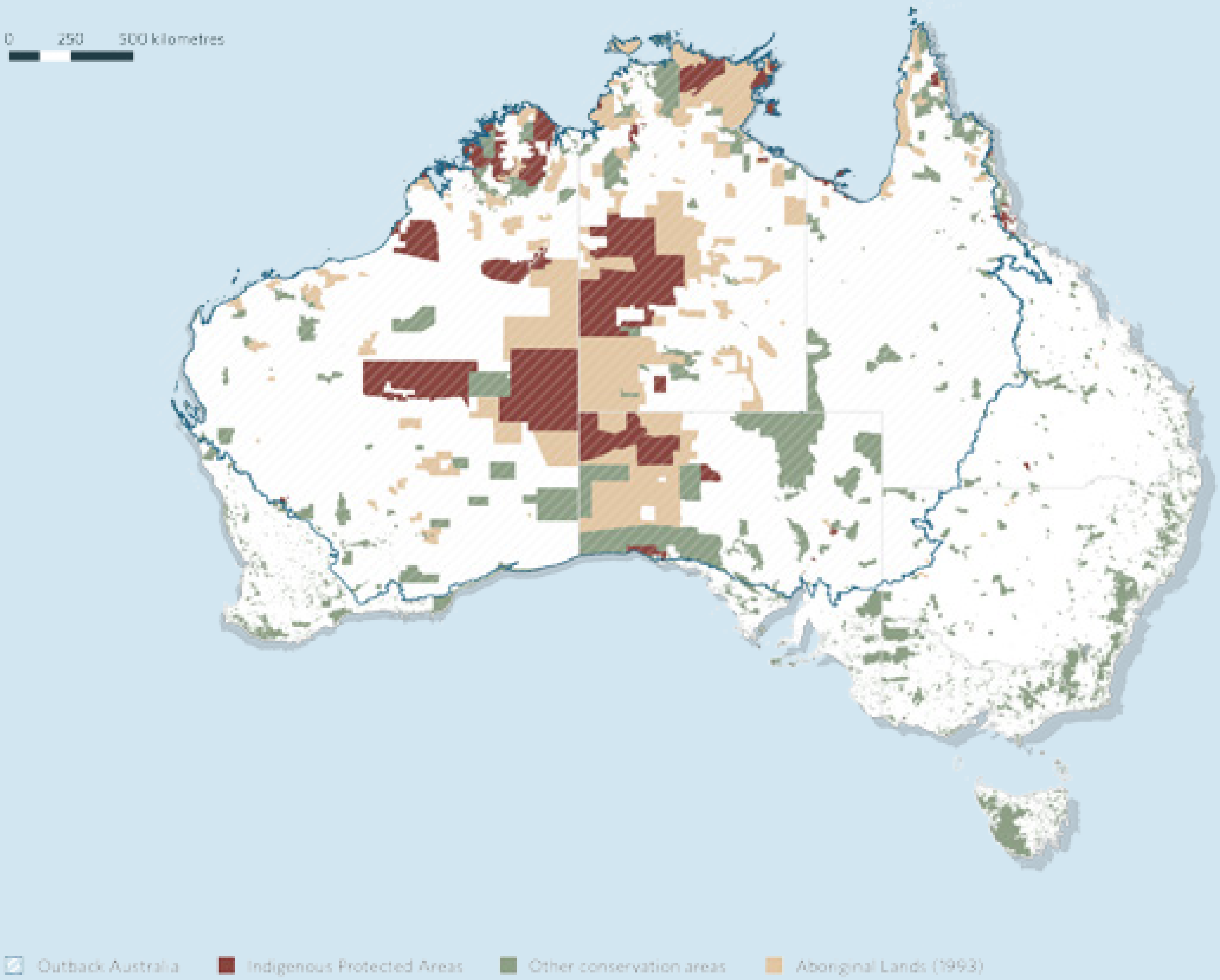
Source: Data to May 2014 from the Australian Department of the Environment

Table design by The Pew Charitable Trusts

Figure 52

The Location of Indigenous Protected Areas, Other Conservation Reserves and Aboriginal-owned Lands, August 2013

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: degree



Source: Australian Department of the Environment

Figure design by The Pew Charitable Trusts

The IPA program is based on international acceptance of the need and opportunity to integrate conservation actions with cultural and socio-economic aspirations, such as is recognised in the Millennium Development Goals (e.g., Table 9). In the Outback context, this is most notably relevant in the synchrony between Aboriginal cultural obligations to maintain the condition of their country and biodiversity conservation objectives. There is now substantial evidence that IPAs, and their associated Indigenous ranger groups, deliver not only benefits to biodiversity but also significant health, employment, education and economic benefits to the typically severely disadvantaged remote communities in which they are based (see Spotlight 8).

Table 9

United Nations Convention on Biological Diversity

Strategic Plan for Biodiversity 2011–2020 Aichi Biodiversity Targets

Strategic Goal A	Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society
Strategic Goal B	Reduce the direct pressures on biodiversity and promote sustainable use
Strategic Goal C	Improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity
Strategic Goal D	Enhance the benefits to all from biodiversity and ecosystem services
Strategic Goal E	Enhance implementation through participatory planning, knowledge management and capacity building

Source: Data to May 2014 from the Australian Department of the Environment

Table design by The Pew Charitable Trusts

Most of the financial base for IPAs and Indigenous ranger groups has been provided through short-term funding from the Australian Government. A series of reviews has demonstrated substantial returns on such investment and led to extension and expansion of the IPA program, and somewhat more secure and longer-term funding (Gilligan 2006). In some cases, this IPA funding has been augmented by investments or other inputs from conservation NGOs, by direct investments as offsets or compensation by mining companies and by carbon trading in relation to the management of fire and stock.

In addition to the development of the IPA program and expansion of lands managed for conservation by NGO groups, there have been some more localised contributions to conservation management on lands primarily used for other purposes.

Associated with developments of major gas, oil and mineral production in the Outback, and of its processing, there has been some increasing use of regulatory instruments to develop compensatory biodiversity management funding, typically hinged on a rubric of 'no net biodiversity loss' or 'overall biodiversity gain'. Some recent examples from the Outback include a series of translocations to mainland areas and other islands for threatened wildlife affected by the establishment of the Gorgon Gas processing plant at Barrow Island (Environmental Protection Authority 2003; Office of the Appeals Convenor 2009), and broad-scale fire management and mitigation programs associated with development of a gas processing plant in Darwin Harbour (Whitehead *et al.* 2009). Such programs vary substantially in legislative basis between the Australian Government and Outback state and territory governments, and in their practice, scale and uptake. Their justification and application remain contested.

Given the extent of pastoral holdings in Outback areas, there is increasing awareness of the contribution that pastoral lands may make towards a more effective conservation reserve system. The form of this contribution has been varied, but most typically it involves using short-term government grant funding to manage weeds or feral animals, and sometimes to establish stock exclosure fencing around environmentally sensitive sites. More systematically, pastoral lease regulations have been subject to recent or ongoing review in most Outback jurisdictions. The current pastoral lands review process in Western Australia has led to government recommendations and actions to excise some parts of pastoral leasehold lands to be formally added to existing, or to establish new, conservation reserves, and to buy out some non-viable pastoral operations. In other cases, some pastoral landholders have voluntarily entered 'land-for-wildlife' or comparable schemes that recognise a commitment to manage the property (or parts of the property) to achieve specific conservation outcomes. The Delbessie Agreement in Queensland sought to formally recognise such contributions, in some cases with trade-off for longer lease terms or freeholding of title (Queensland Department of Natural Resources and Water 2007). However, for most Outback jurisdictions, there are regulatory constraints on activities on pastoral lands (in many cases, minimum stocking levels) and constraints that ensure that pastoralism remains the primary use of the land. Such constraints limit the opportunities for diversification, including for conservation management (Dale *et al*. 2013).

> Given the extent of pastoral holdings in Outback areas, there is increasing awareness of the contribution that pastoral lands may make towards a more effective conservation reserve system.

One other factor that has contributed to the increasing acceptance of conservation as a significant land use for the Outback is its economic efficiency. In more settled parts of Australia, land prices are typically appreciably higher than in the Outback, often making the acquisition of land for conservation in these areas prohibitively expensive and subject to competition with other potential and economically potent land use. Hence, government and non-government conservation agencies with limited budgets are more likely to achieve substantial conservation outcomes from their budgets in the Outback than elsewhere (Carwardine *et al.* 2006). Furthermore, the developing carbon market provides a potential supplementary opportunity to fund the acquisition of, and manage, conservation reserves, especially in higher-rainfall Outback areas (Douglass *et al.* 2011). However, the policy instruments that could support such investment remain unsettled.

Over the last decades there has been a substantial increase in the extent of Outback lands devoted to conservation (Figures 53, 54), with a higher rate of expansion than for non-Outback areas. Most of this increase is due to the establishment of large IPAs. However, this expansion has not been consistent across the Outback and there remains a marked disparity between Outback regions: those with highest pastoral productivity remain poorly represented in the conservation reserve network (Table 10).

Taken together, this diverse set of initiatives has significantly enhanced and changed the conservation reserve system in the Outback (Table 11).

> The reserve system is good, but not yet great, and it does not yet match the international significance of the Outback's natural values.

The current Outback conservation reserve system now represents a strong foundation. Most of the iconic sites are included within conservation reserves, and these are complemented by a series of broad-scale landscape conservation areas (mostly as IPAs). The reserve system is good, but not yet great, and it does not yet match the international significance of the Outback's natural values.

8.3. The importance of greenhouse gases

Characteristics once seen to be worthless may become economic assets in a changing world. For the Outback, this applies particularly to the carbon market. While unit prices for some carbon commodities in the Outback may be small, the vast extent of the Outback – and of many property holdings within it – renders the sum of these values across extensive areas to be substantial. This is particularly so relative to the marginality and/or unpredictability of many other potential land uses or economic opportunities. Since the late 1990s, there has been escalating interest in the carbon market, particularly in relation to reducing emissions from wildfires in savanna environments (see Spotlight 10). There is also some scope for carbon trading in other activities, including reducing livestock numbers, controlling feral stock, establishing plantations, protecting woodlands otherwise proposed for clearing and sequestration in soils (Van Oosterzee and Garnett 2008; Murphy *et al.* 2009; Douglass *et al*. 2011; Law and Garnett 2011; Grover *et al.* 2012; Heckbert *et al.* 2012; Pearse 2012; Bradshaw *et al.* 2013).

The economic landscape is unsettled because of uncertainty in Australia and globally about carbon pricing and policy instruments. There are also issues around the regulatory obligations for some land tenures and about ownership of carbon rights. Unlike the north, the carbon economy in arid and semi-arid Outback areas may be constrained by the highly variable climate – with long periods of little rainfall and limited vegetation growth – and the relatively low productivity, plant biomass and fire frequency. One other complication is the detrimental impacts on the carbon economy of invasive pasture grasses. Given that areas invaded by such species carry fires of higher intensity (and hence greenhouse gas emissions) and that fire is far less controllable in such areas, further spread of these weeds substantially compromises emission abatement projects and can swing projects from reliable, profitable and achievable to high risk and economic loss (Adams and Setterfield 2013).

Notwithstanding these constraints and uncertainties, recent analyses consistently indicate that broad-scale fire management for greenhouse gas abatement is economically viable across extensive areas of the monsoonal tropics of northern Australia (Heckbert *et al.* 2012). The establishment and success to date of a growing number of examples indicates that such projects are practical and can attract substantial commercial investment. Furthermore, other analyses indicate that biomass sequestration projects can deliver substantially higher economic returns than for emission abatement (Murphy *et al.* 2009).

Table 10

Reservation Extent of Outback Bioregions

% of bioregion reserved	Bioregions
<1%	Sturt Plateau
1–5%	Gulf Plains, Broken Hill Complex, Little Sandy Desert, Mount Isa Inlier, Davenport Murchison Ranges, Mitchell Grass Downs, Dampierland, (Desert Uplands, Mulga Lands)
5–10%	Finke, Daly Basin, Gulf Fall and Uplands, Channel Country, Pilbara, Central Arnhem, Stony Plains, Murchison, Einasleigh Uplands, Burt Plain, (Flinders Lofty Block, Brigalow Belt South)
10–25%	Gulf Coastal, Tiwi–Cobourg, Northern Kimberley, MacDonnell Ranges, MacDonnell Ranges, Gawler, Victoria–Bonaparte, Great Sandy Desert, Hampton, Coolgardie, Ord–Victoria Plain, Central Kimberley, Carnarvon, Gascoyne, (Mallee)
25–50%	Tanami, Pine Creek, Arnhem Coast, Gibson Desert, Yalgoo, Nullarbor, Darwin Coastal, Simpson–Strzelecki Dunefields, Great Victoria Desert, Cape York Peninsula,
>50%	Arnhem Plateau, Central Ranges

Note: Brackets indicate bioregions that are only partly in the Outback.

Table design by The Pew Charitable Trusts

Table 11

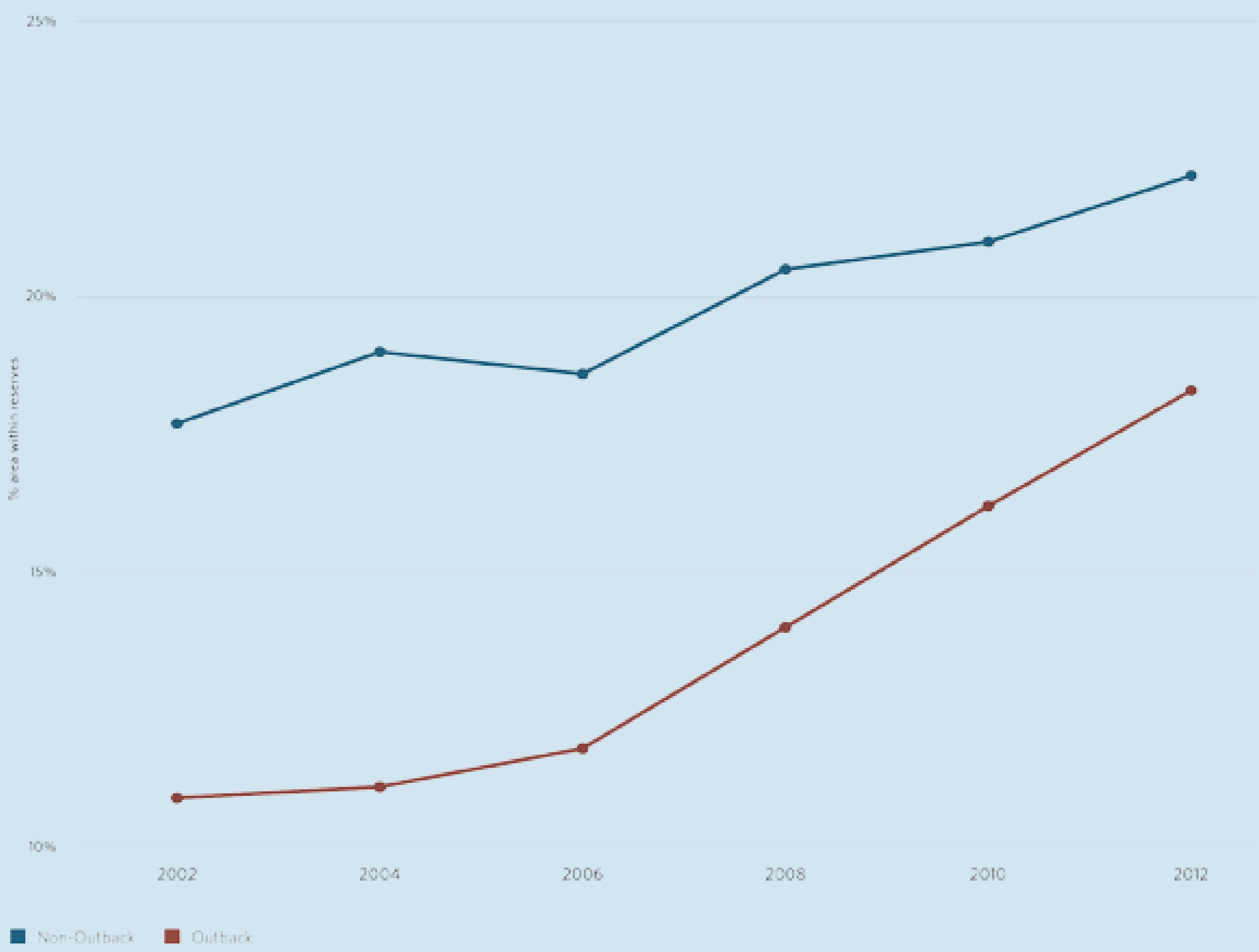
Summary of the Changing Nature of National Parks and Conservation Reserves in the Outback

Conservation management characteristic	Status 1–2 decades ago	Current status
Primary purposes of the conservation reserve system	Protection of iconic tourism sites, sampling of all major environments, management of threatened species	Maintenance of critical ecological processes and function, linkages across large landscapes, landowners engaged in conservation management, protection of iconic tourism sites, sampling of all major environments, management of threatened species
Responsible management authority	Government conservation agencies	Government conservation agencies, Indigenous groups, conservation NGOs, and to some extent with contributions from pastoralists and mining/gas companies
Extent	c. 10%	c. 20%
Comprehensiveness and representativeness	Fair, but low representation of more productive environments	Good, but low representation of more productive environments
Conservation management activity	Mostly limited control of major pests and weeds, and some fire management	(i) Intensive management of some threats (notably feral predators) at some localised sites, (ii) mostly limited but increasingly regionally integrated control of major pests and weeds, and some fire management, (iii) management recognised as based on culture and traditional knowledge
Parks in context	Conservation will be achieved with a discrete system of reserves	Conservation reserves are a focus for intensive land management, complemented by extensive and coordinated threat management across entire landscapes

Table design by The Pew Charitable Trusts

Figure 53

Changing Proportional Extent of Conservation Reserves in Outback and non-Outback Australia



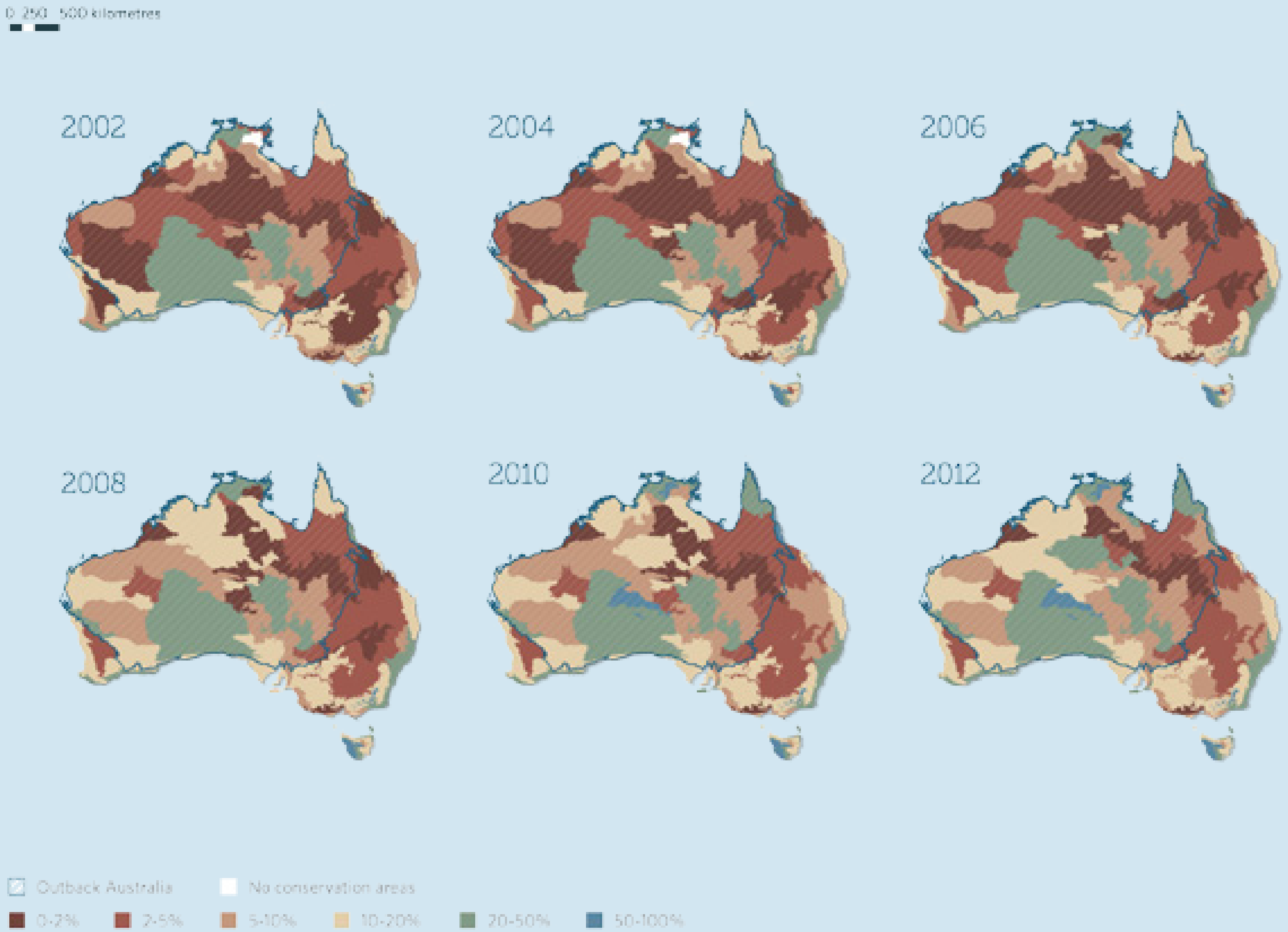
Source: Derived from the Collaborative Australian Protected Areas Database

Figure design by The Pew Charitable Trusts

Figure 54

Increase in Reservation Status Across All Australian Bioregions, 2002–12

Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: degree



Source: Collaborative Australian Protected Areas Database

Figure design by The Pew Charitable Trusts

8.4. Energy resources and costs

Energy is a key concern, constraint and opportunity for the Outback. The very large distances between most Outback communities and major infrastructure centres impose a significant cost on the delivery of power and therefore reduce enterprise competitiveness and the attraction of the Outback for settlement. And energy demands may be substantial given the challenging climate. Currently, the Outback 'is heavily reliant on diesel generators and fossil fuel-powered motor vehicles and airplanes for transport for within-region mobility, the importation of goods, the tourism industry and emergency medical services' (Pittock 2011). A future of more extreme climatic conditions, and of reduced supplies of non-renewable energy, will exacerbate this disadvantage and make many Outback communities even more marginalised.

However, parts of the Outback have substantial developed and undeveloped gas resources, and all of the Outback has enormous resources of renewable energy that can provide – and in an increasing number of cases, are already providing – relatively cheap sources of local power.

'Desert/remote Australia is blessed with abundant natural energy resources from solar, geothermal and other renewable sources. If these were harnessed and connected appropriately desert/remote Australia could be not only energy self-sufficient but a net exporter. Generation of abundant, clean energy can also attract energy-intensive industries and provide local income and employment' (Pittock 2011).

There is a high potential to meet some of the energy needs facing Outback communities by using smart technology that draws on available resources, such as sunlight. Solar arrays in many remote communities are now providing a cleaner and more efficient power generation system than traditional sources. At Yuendumu, Lajamanu, and Hermannsburg, these are already saving 420,000 litres of diesel and 1550 tonnes of greenhouse gas emissions every year (Ferguson 2012).

This substantial solar power station established at Hermannsburg, near Alice Springs in the Northern Territory, meets around half the daytime energy needs of the town's 600 residents. Access to solar power reduces the community's reliance on costly diesel generators, as well as significantly lowering the town's greenhouse gas emissions.

‘The potential for wider adoption of this technology is enormous. With the evolution of low-loss power transmission, the opportunity will open up to ship electricity from remote Australia direct to the cities, factories and cars of the eastern seaboard – or even to the industrial heart of Asia, using energy superhighways’ (Ferguson 2012).

One other emerging issue relating to energy future in the Outback involves a recent series of proposals for the development of a biofuel industry, notably including the development of extensive plantations of two highly invasive plants, Physic Nut and Giant Reed. To date, such proposals have not eventuated, in part because of the recognition of environmental risk.

8.5. Demographic and governance changes

Workplace practices for most mines have changed notably in the last decade, with many mining communities established as ‘moon bases’ – impermanent serviced hostels for fly-in fly-out workers. Some recent policy changes, such as the ‘Royalties for regions’ program in Western Australia, have sought to reduce the net drain of benefits away from these Outback centres to instead establish more enduring infrastructure, services and communities in the wealth-generating areas.

Many recent government policy initiatives have sought to redress the chronic neglect of Outback communities through programs aimed mostly at Indigenous disadvantage. Notable, but not necessarily notably successful, examples include the Council of Australian Governments ‘Shared Responsibility’ trials aimed at improving efficiency through consolidating multiple government services at remote Indigenous communities such as Wadeye in the Northern Territory (Strakosch 2009), the Australian Government’s Northern Territory emergency response intervention into Indigenous welfare issues (Altman 2007), and a series of administrative and governance changes relating to the servicing of outstations and consolidating regional and local government (Walker *et al*. 2012).

8.6. Technological advances

Recent technological advances are addressing some of the disadvantages of living in the remote Outback.

Satellite and other imagery is being more widely used, and with increasing precision, as an important tool for a range of uses, including to monitor landscape condition and fire history over vast areas (Bastin and ACRIS Management Committee members 2008), adjust livestock grazing pressure, identify areas of mineral prospectivity, map rainfall and water movement and availability, help tourists navigate the Outback, prioritise areas for fire management, monitor vegetation clearing and map the movements of wildlife species. For example, ‘precision pastoralism’ and ‘Watersmart’ technology, based on telemetry and satellite monitoring, is now improving knowledge of livestock impacts and water availability to increase pastoral profitability and sustainability (James and Bubb 2008; James and Driver 2008).

Such technological advances are making the Outback more tractable and reducing the tyranny of distance. The Global Positioning System and Geographic Information Systems are now standard tools for miners, local government, many Aboriginal ranger groups and pastoralists, allowing a far higher standard and interchangeability of data across a wide range of Outback disciplines and regions.

Greater understanding of complex weather systems and increases in computer power are also leading, gradually, to an enhanced capability and capacity to predict, and hence prepare for, drought, floods and cyclones, and to manage pastoral production – for example the AussieGRASS program (http://www.longpaddock.qld.gov.au/about/researchprojects/aussiegrass).

Although still generally markedly inferior to those in more settled areas, communications are also improving in the Outback, with an increasing reliability, coverage and uptake in Internet connections and phone coverage, decreasing the sense of isolation of many remote communities and increasing the quality of health, education and business services.

Some Outback centres – most notably Darwin and Alice Springs – have now also developed substantial health, education and environmental research and management industries, and these are becoming a significant economic and employment contributor, often with substantial export value for tropical and desert countries elsewhere.

8.7. The ‘Develop the North’ vision

A perception of abundant water, extensive and cheap land, and proximity to vast markets in Asia has recurrently fuelled visions of monsoonal northern Australia transformed to intensive horticulture, with the scale of enterprise sufficient to overcome the tyranny of distance threshold and to drive regional economies, substantial employment, and diversification. In this vision, initial investment will reap eventual economic rewards, as the unproductive wastelands and troubled and meagre socio-economic communities are transformed to productivity and profitability.

This is a persistent vision, periodically championed by governments, with notable initiatives over the last decade and now. Unusually, in response to one recent wave of development enthusiasm, the Australian Government established in 2007 a comprehensive scientific assessment of the land and water potential of northern Australia, and its capability for use, in the form of a Northern Australia Land and Water Taskforce. That review, completed in 2009, concluded that there was some, but only modest, potential for agricultural intensification in northern Australia – up to about 60,000 hectares – with the major constraint being the limited and fragmented extent of fertile soils and the relative intractability of water availability. The report noted that:

'The north is not a vacant land. It needs to be actively managed for resilience and sustainability, based on a contemporary and informed understanding of the complexities of the landscape and its people. Contrary to popular belief, water resources in the north are neither unlimited, nor wasted. Equally, the potential for northern Australia to become a 'food bowl' is not supported by evidence. Future development needs to be smart and build on the area's special attributes. While there are opportunities for agriculture to grow, particularly the pastoral industry, there are also limits to available water and suitable agricultural soils. Building the adaptive capacity of landscapes and the resilience of communities to respond to climate change will be important. Developments that further disadvantage Indigenous people are also a concern and are contrary to national policy' (Northern Australia Land and Water Taskforce 2009).

Comprehensive scientific assessments commissioned for that review countered the misperception that there was abundant unused and wasted water in northern Australia that should instead be diverted to horticultural and other purposes:

'All water is fully in use. The water balance is closed; even 'wasted' water running out to sea is needed by estuarine systems and near-shore ecosystems. Whilst current levels of use are low relative to total water stocks, any perturbation will have consequences through the hydrological cycle' (Cresswell *et al*. 2009).

Nonetheless, the current Australian Government remains enthusiastic about broad-scale transformation, with claims that northern Australia 'remains under-utilised relative to the rest of the country' and that with intensive development catalysed by supportive government policy 'the rise of these regions, underpinned by a set of global macro-trends, will create significant opportunities for Northern Australia to capitalise on its strengths and unlock major economic value' (http://www.liberal.org.au/2030-vision-developing-northern-australia). It is progressing this objective through the current development of a White Paper to frame, develop and implement such policy. Complementing this initiative is a current Australian parliamentary Joint Select Committee on Northern Australia, whose primary terms of reference are:

'the committee consider policies for developing the parts of Australia which lie north of the Tropic of Capricorn, spanning Western Australia, Northern Territory and Queensland, and in doing so:

(a) examine the potential for development of the region's mineral, energy, agricultural, tourism, defence and other industries;

(b) provide recommendations to:

(i) enhance trade and other investment links with the Asia–Pacific;

(ii) establish a conducive regulatory, taxation and economic environment;

(iii) address impediments to growth; and

(iv) set conditions for private investment and innovation;

(c) identify the critical economic and social infrastructure needed to support the long-term growth of the region, and ways to support planning and investment in that infrastructure'

This theme represents one possible future for at least large sections of the northern Outback. It is notably narrowly focused on conventional projects and environmental transformation and still sees the environment mainly as a constraint to be overcome, rather than as the basis for a sustainable future.

> Such a quintessential Australian environment should not be squandered through careless ignorance, not-so-benign neglect or attempts at short-term profiteering.

9. Sustaining the Outback

'The rangelands can have a rich and exciting future, but this future will only be realised by looking forward, by thinking differently about the range of values the landscape has to offer' (Fitzhardinge 2012).

'New approaches, new thinking and new commitment are urgently needed in regard to remote Australia. With … so much at stake, more of the same – or working harder on and inherently perpetuating the old 'solutions' – is not an option' (Walker *et al*. 2012).

From an unsettled present-day position, the Australian Outback has a range of potential futures, which may be realised by default and inaction, or by deliberate choice. The fate of the Australian Outback is one of the nation's most important choices. Can we pursue genuine sustainability? This choice is real and urgent, but has been neglected. And in the absence of deliberate choice, ad hoc development – or systematic development divorced from considerations of sustainability or environmental cost – is chipping away at what is distinctive about the Outback and undermining opportunities to choose a sustainable future.

> The fate of the Australian Outback is one of the nation's most important choices. Can we pursue genuine sustainability? This choice is real and urgent, but has been neglected.

One possible future – more or less the default 'business as usual' option – is for ongoing neglect, with little strategic investment, ongoing reduction in the Outback's importance to the national economy and character, failing communities and environmental degradation. This is an unjust option and provides little or no benefit to any group. It would simply compound existing problems or create new ones.

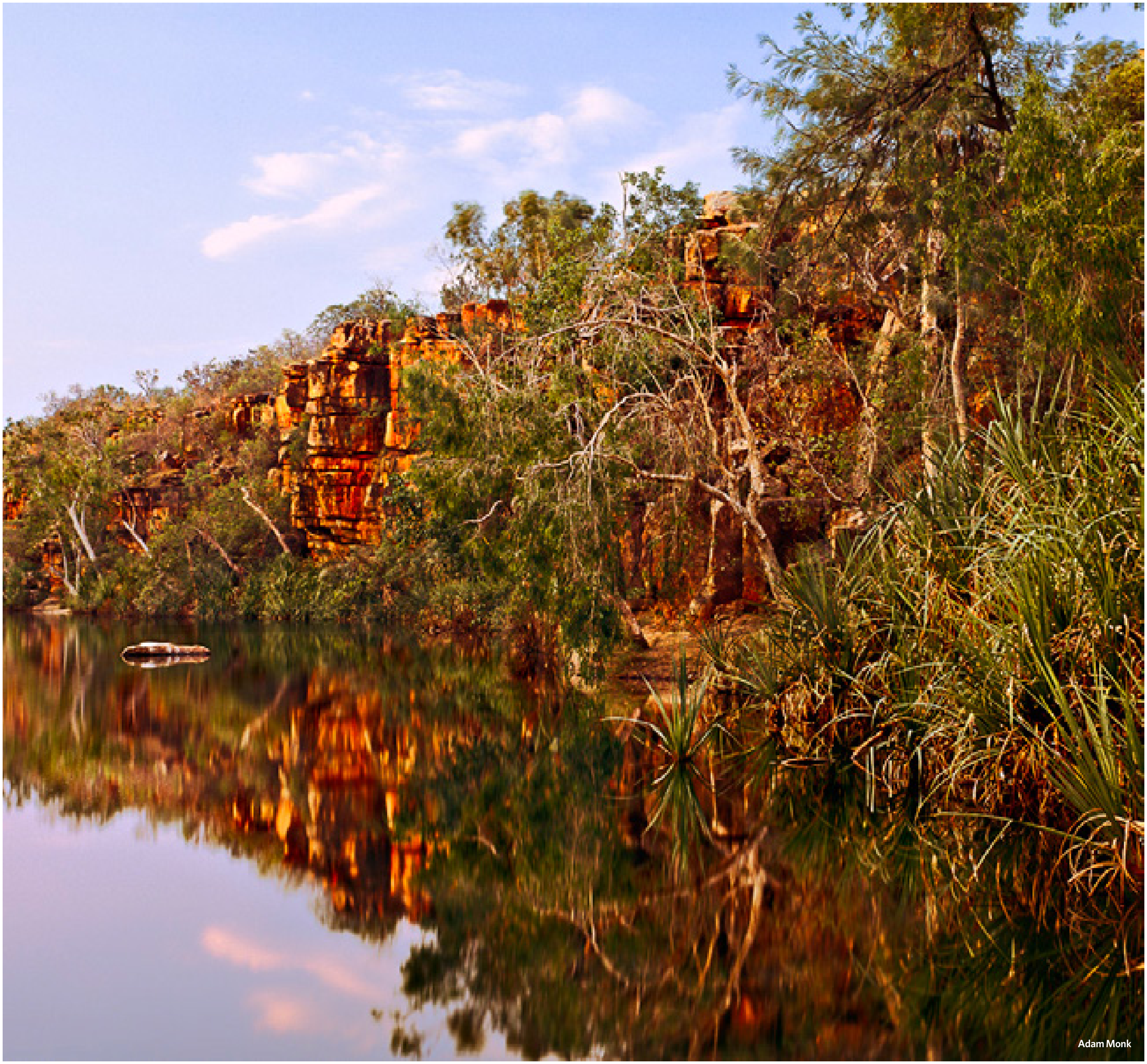
Another imagined future is to treat the Outback as any other land ripe for development. It would divide the Outback landscape into exploited and conserved sectors and seek to overcome the logistical and environmental constraints through government investment and drive. It would seek to capture the Outback's elusive resources in order to develop intensive agriculture and to create a society that moves from the frontier (or the backblocks) to the mainstream. This option is unlikely to succeed and would cause irredeemable loss of those values that make the Outback so distinctive and valuable.

There is a different future that instead recognises the wonderful existing inherent value in the Outback, that works within the environmental and other constraints, that recognises opportunities for cultural and socio-economic advantage in extensive land management and in compatible development, and that sustains and enriches the Outback character, environment and culture. This alternative is achievable and desirable. It would build from a firm foundation. It would do the most to maintain, and benefit from, the values of the Outback.

> One imagined future is to treat the Outback as any other land ripe for development. This option is unlikely to succeed and would cause irredeemable loss of those values that make the Outback so distinctive and valuable.

The intact nature of the Outback and the natural resources that flow from healthy landscapes underpin many of the economies that support people in the Outback lands. Planning for the Outback's future is a different proposition to that conventionally applied to most other landscapes. Rather than preserving remnants and attempting to restore connections between them, Outback life is about maintaining the intact landscape and the essential connections between living and non-living elements, and between people and the land. Protecting only parts will compromise the whole. Protecting parts is the mentality that has emerged from damaged landscapes in other parts of the world where there are only fragments left over from development. Culturally, too, the Outback's immense values for both Indigenous and non-Indigenous Australians rely on maintaining intact and healthy landscapes. It is not enough to cordon off some sites or properties as culturally important, for their living significance is linked to whole landscapes. Social and economic sustainability is also linked to healthy and unbroken landscapes.

There is a need for action. Rather than being the centre points of the Outback's future, its values are now being whittled away, deliberately or inadvertently and often without immediate or general recognition of such loss. Without strategic action, the pace and magnitude of such loss are likely to increase. Such losses would make the Outback less distinctive and reduce its international significance and interest. They would erode the culture and heritage of Aboriginal landowners and represent a failure in the obligation to look after country – to pass the land in a healthy and productive condition to the next generations. But even more so, the degradation of environmental processes in the Outback will weaken the fabric of life there and diminish and compromise the foundation for human life and enterprise in these lands.



Barnett River Gorge on Old Barnett Station is one of the many gorges along the Gibb River Road in Western Australia's Kimberley region. The road runs through some of the most picturesque and remote country in Australia.

> Rather than preserving remnants and attempting to restore connections between them, Outback life is about maintaining the intact landscape and the essential connections between living and non-living elements, and between people and the land. Protecting only parts will compromise the whole.

Space and light distinctively frame the Outback. It is a vast landscape of big skies and far horizons, but also of subtleties whose functional importance may be discerned only with care and familiarity. Those working with this landscape, and crafting its future, need:

- hindsight – learning from mistakes made elsewhere to avoid damaging what is special about the Outback;
- insight – applying ecology, respecting cultures, and promoting social justice to choose a genuinely sustainable future; and
- foresight – tracking trends and anticipating changes to plan for human wellbeing and ecological health beyond the present.

9.1. Lessons from the land

In this report, we have sought to characterise and contextualise the Australian Outback. Planning for a sustainable future for the Outback cannot work against these traits but rather should be based on them. In Table 12, we draw management and policy lessons from these Outback characteristics.

Collectively, these components form a foundation for crystallising the main challenges affecting the Outback now and into the future. They also form the foundation for a coherent vision for the Outback's future and a pathway to the realisation of that vision.

9.2. Lessons from elsewhere

There is no place in the world quite like the Australian Outback. So, much of the way in which it should be managed needs to be developed intrinsically in response to its unique character and challenges.

However, there are notable precedents elsewhere in the world that can contribute useful lessons for such management. The most relevant such international examples are recent successes in large-scale conservation management in the boreal forests (the Canadian Boreal Initiative) and large-scale connectivity projects such as the Yellowstone to Yukon conservation initiative of North America. Superficially, these are very different places to the Outback. They are cold, wet, green, rugged, and densely forested. But the Outback and these North American examples share many similarities. They are large (continental-scale), but coherent entities. They have long been at or beyond the frontier between the 'wild' and the tamed. They have relatively few people but a high proportion of the population is Indigenous. They are remote from main centres of power and influence. Their economies are relatively limited but there are pockets with vibrant economies largely driven by companies remote from the region. Both the Outback and these North American examples are also characterised by extensive and largely intact natural environments, varying subtly over large areas.

> Reviews of conservation planning initiatives done around the world provide further direction by indicating that protected areas should cover in the range of 50 per cent of the landscape to achieve these objectives.

The boreal forests example applies some general objectives and tenets of conservation biology: 1) all native ecosystem types must be represented in protected areas; 2) populations of all native species must be maintained in natural patterns of abundance and distribution; 3) ecological processes such as hydrological processes and fire must be maintained; and 4) the intactness and functionality of ecological systems should be retained for those systems to be as resilient as possible to new threats.

Achieving these objectives requires an extensive interconnected network of protected areas and sustainable management of surrounding areas. Reviews of conservation planning initiatives done around the world provide further direction by indicating that protected areas should cover in the range of 50 per cent of the landscape to achieve these objectives (Locke 2013).

The North American programs demonstrate that significantly improving continental-scale conservation and sustainable development is achievable and can deliver multiple benefits. Some of the key features of these programs have been described in recent reviews and frameworks (Soulé and Terborgh 1999; Badiou *et al*. 2013; Locke 2013). Those most relevant to the future of the Outback include:

Table 12

Outback Characteristics Provide the Framework for Crafting a Sustainable and Modern Outback

Outback element	Guidance from this characteristic for a sustainable Outback future
The Outback is of international significance.	We need to see and manage the Outback as a coherent entity, because its worth is greater than the sum of its iconic components. In a world of diminishing nature, the Outback will be increasingly valued at a global scale. We should not jeopardise that value.
There is little or no coherent planning or management across the Outback – it is more or less arbitrarily segmented.	Management, planning, and governance will be effective and cost-efficient only when the Outback is recognised as a coherent entity. There is scope and need for far more substantial collaboration across jurisdictions and tenures .
Some components of Outback biodiversity are declining. The threats are significant and existing management is insufficient.	There is an urgent need for action to maintain the Outback's values. The loss of individual components of biodiversity is likely to have further repercussions, because such losses will disrupt ecological processes. Current management approaches and effort are inadequate to protect environmental values. The challenge will be met only by enhanced collaboration,having more people actively managing the land, and large-scale and long-term strategic responses.
Maintaining indigenous culture has much in common with, and is conducive to, effectively managing the land.	The expanding network of Indigenous Protected Areas and Indigenous ranger groups provides an important basis for enhancing conservation management across the Outback, while also addressing critical social and economic challenges.
Historic legacies of land tenure and use are a suboptimal foundation for the future.	In parts of the Outback, current land tenure or use may be an ill-fitting legacy of historical factors. And in some places this land tenure or use may cause environmental detriment without delivering social or economic benefit. A more rational, considered and forward-looking consideration of land tenure, use and policy is required.
In a dry land, water is a pivotal resource.	Much of Outback ecology pivots on water, which is typically the primary contested zone for exploitation and disturbance. Given water's critical role in processes underpinning the Outback's ecology, management and planning should ensure that its exploitation is constrained within safe environmental limits.
Climate change will exacerbate some existing challenges for Outback life.	It will be necessary to maintain broad-scale connectivity across the landscape to allow species to move to different locations in response to changing climates. This is more likely to be achievable in the Outback than in more intensively settled parts of the world. Refuge areas will become of even more paramount importance, so need to be protected and well managed. In arid and semi-arid Outback areas, water resources may be subjected to increased pressure, so current use and management of those resources should be conservative.
The economic fabric of Outback society is fragile and, in part, divided into rich and poor districts.	Planning and management for the future of the Outback should be based on more secure, longer-term funding. Nodes of economic profitability in the Outback, such as major mining enterprises, should invest significantly in broader regional, social and environmental concerns aimed at achieving positive long-term impacts.
Some iconic places in the Outback are well known and relatively well protected.	Such locations provide flagships and critical core sites for conservation in the Outback, and they raise public awareness through research and tourism, but they will be inadequate by themselves to maintain Outback nature. Even these iconic areas will be diminished if their surrounds are not also protected.
Refugia and nodes of species richness and endemicity (species found only in localised areas) are critical for biodiversity conservation, and particularly so in low-productivity and boom–bust systems.	All areas that are critical for biodiversity need to be identified, protected, and managed appropriately – or else biodiversity will fail across large areas.
Many animal species must disperse across the Outback to find food and water.	Broad-scale habitat must be maintained across the spectrum of species whose survival in the Outback depends on dispersal. This particularly includes the protection from catchment to coast (or to inland terminus) for Outback river systems. The land-allocation model of nature being represented in fragments, even large fragments, is inappropriate for the Outback. Entire landscapes, and the ecological processes structuring them, need to be protected. Reservation is necessary but not sufficient: conservation areas also need to be appropriately managed.

Table design by The Pew Charitable Trusts

- the establishment of an ambitious and inspiring conservation objective;
- the recognition of shared values, and the development of effective partnerships, among diverse sets of people resident and with interests in the area;
- the primacy of planning and management to maintain ecological processes operating over very large areas;
- respect for the lands, rights and way of life of Aboriginal people, and of the significance of their knowledge and role in looking after the lands;
- the recognition of the need for core conservation reserves encompassing sites that are critical for biodiversity, with complementary conservation management of connecting lands;
- the recognition of conservation management as a mechanism to deliver significant social and economic benefits for Indigenous people, and other residents;
- the recognition that planning, management, and policy should be evidence-based, with that evidence deriving from science, traditional knowledge, and local perspectives; and
- the recognition that development is a desirable necessity, as long as it is compatible with the overarching conservation objective, and sited and managed in a manner that does not disrupt important ecological processes.

Much remains to be achieved on the ground and debate over the best approaches continues in these regions in North America, but these principles and practices have worked to achieve substantial progress in the resolution of environmental and social challenges in that continent. They can also be applied to help deliver a sustainable future to the Outback.

9.3. Components of a sustainable Outback future

Recognising Outback values

Essential for driving wise choices is a greater national recognition that the Outback is special and that there are compelling ecological, cultural, social and economic reasons to plan for and protect it as a whole.

Deeper national recognition of the extraordinary natural and cultural values of the Outback is essential to motivate Australians to demand or support its protection and to reject competing and implausible visions. Many Australians have a caricatured perception of the Outback. We need to move beyond the varied simplifications. As one of the world's largest great natural regions with life adapted in many ingenious ways to its boom and bust cycles, the Outback offers many tangible and intriguing reasons for cultural celebration. Such a quintessential Australian environment should not be squandered through careless ignorance, not-so-benign neglect or attempts at short-term profiteering.

In a recent review of the state of Outback communities, and of their future, Jan Ferguson recognised that:

' ... the future of the rangelands lies in a subtle shift from seeing agriculture as of primary importance, to recognising the array of alternate values that the majority of contemporary Australians place on inland Australia and its natural heritage' (Ferguson 2012).

Deeper national recognition of the extraordinary natural and cultural values of the Outback is essential to motivate Australians to demand or support its protection and to reject competing and implausible visions.

Collectively, Australians and others must recognise that the Outback is worthy of our attention and investment, and that the vibrant culture and functional environments of the Outback are an asset that benefit us all:

'If non-metropolitan Australia is going to need some degree of subsidy, then it needs to be underpinned by a renewed understanding of the benefits the city gets from the country. Otherwise it simply becomes a form of welfare, smoothing the dying pillow of old-timers in obsolete country towns and helping leave the land through adjustment schemes' (Brett 2011).

Recognising a need for action

Over recent decades, many of the deeply ingrained social and economic fault lines in the Outback have been recognised by governments and the Australian community more generally. We note here that many Outback environmental values are also at serious risk. These issues will not be solved by piecemeal approaches or doctrines imposed on the Outback. The state of the Outback needs to become a matter of national attention.

'To not respond to evidence of persistent systemic failure is to effectively dispute that evidence, or to imply that a response would be of little or no consequence. Even worse, it is to suggest that the people of remote Australia are not as important as people living in the populated cities along the coastal fringe. It is not a case of whether or not we know what to do, but rather of having the collective will to do it. The market will not define the national interest in remote Australia and its peoples. Only political and civic leadership will drive the necessary reforms. It is easy politics to hide behind concepts of representational democracy and market economics and waive the needs of remote Australia in favour of the weight of public opinion and numbers in the serviced suburbs. For it is here that the majority of political leaders derive their authority and maintain their relevance. This type of neglectful inequality is corrosive for the nation and rots Australia from within' (Walker *et al*. 2012).

> Places such as Uluru or Kakadu are part of the fabric of the Outback. However, their ecological function and social, economic and environmental values will falter if the nature in which they are embedded is dissected, disrupted and degraded.

Protecting landscapes

We started this report with appropriate homage to some of the Outback icons. Places such as Uluru or Kakadu are part of the fabric of the Outback. However, their ecological function and social, economic and environmental values will falter if the nature in which they are embedded is dissected, disrupted and degraded. These icons, like their counterparts around the world, need to be considered and managed as part of larger landscape in order to maintain their values (Editors of *Nature* 2011).

Our conservation horizons should be as expansive as those of the landscape. To maintain ecological health across these lands of subtle variations and complex, long-distance connections, it is not enough to focus conservation on the scattered icons or on representative patches – even large patches – in the landscape. We need to disown the perspective inherited from fragmented Europe that 'some vestiges of natural areas should be retained as representative showpieces' (Garnett *et al*. 2010). Conservation instead needs to be based on a deeper understanding of how nature works in the intact landscapes of the Outback. Because many of the Outback's ecological processes operate over very large distances (see Insight 8 on dust storms), even moderately large reserves are vulnerable to what occurs beyond their boundaries (Woinarski and Whitehead 2005). Many threatened species have small populations spread over extensive and fluctuating distributions. Major threats to landscapes, such as fire and invasive species, cannot be fended off by changing the tenure of an easily definable remnant (Garnett *et al.* 2010). For the Outback to keep functioning, we need more and larger reserves and coherent management across all tenures. The Kimberley EcoFire project and West Arnhem Land Fire Abatement are inspiring examples of how this can occur.

Re-inhabiting the Outback

There is ecological truth to Aboriginal tenets that their country needs them. The emptying of the Outback, with Traditional Owners removed from or leaving their land, and many pastoral properties now with few managers and workers, has left much of the Outback bereft of people to manage fires, weeds and feral animals.

Fundamental to conservation of the Outback is returning people to the land and supporting Indigenous Australians, pastoralists, conservationists and other landholders to manage threats. This requires resources, skills training, wages and information, and the valuing of land management as a vital contribution to a sustainable Australia (Garnett *et al.* 2010). It will require alternative economic options to pay for stewardship on pastoral properties. Conservation management on pastoral properties provides diversification and hence stimulates and maintains a more reliable economy. Properly valuing the worth of land management is one of the most promising ways of addressing the chronic impoverishment of many Outback Aboriginal communities.

Daniel Oades, Bardi Jawi Indigenous Protected Area Coordinator on the Dampier Peninsula north of Broome, Western Australia, works with a team of rangers that are combining traditional knowledge and western science to deliver cultural and environmental benefits.

Insight 8

Dust storms: a cloud on the horizon

The condition of Outback lands reverberates across the rest of the continent. Dust storms are dramatic demonstrations of this as, catalysed by dry conditions and some land use practices,, they build up in remote areas and then affect settled communities, including the nation's major Such storms cause major social and economic detriment along the pathway of their receiving areas.. The estimated off-site economic costs of one such recent storm in New South Wales, in just part of its pathway, was about A$280 million (Tozer and Leys 2013). Costs related mostly to diverting air transport, cleaning costs, and interruptions to construction and other industry.

These storms, such as the one pictured rolling in over Outback New South Wales, also remove much of the limited fertility over large areas of the Outback. There have been many such storms since European settlement, leading to a large, and largely unrecognised, and recurring impact of Outback condition on the nation's fertile fringe. With increased likelihood of severe drought in the future, such events are likely to occur even more frequently.

Rodney Dekker

Appropriate land management, sensitive to the Outback's natural and social values, will ensure its diverse environments can be enjoyed by future generations of residents, workers, tourists, campers and bushwalkers. Pictured, two visitors take in the view from a lookout at Chambers Pillar Historical Reserve south of Alice Springs, in the Northern Territory.

> Fundamental to conservation of the Outback is returning people to the land and supporting Indigenous Australians, pastoralists, conservationists and other landholders to manage threats.

Re-inhabiting the Outback is self-reinforcing. As communities are empowered, develop capacity, and develop enterprises based on sustaining landscapes and culture, remote regions will become more attractive as places to live and work. This will make 'remote communities more diverse and resilient. It sucks in new skills and talents from afar and keeps local ones at home. It attracts more government services and support. It creates self-sufficiency and increases respect among outsiders' (Ferguson 2012).

Integrating economics and conservation

An Outback economy is needed that builds and supports strong, vibrant, sustainable communities; provides meaningful work, good livelihoods and sustainable enterprises; supports Aboriginal culture and conserves and restores the environment.

Conservation of the Outback is feasible only if the work needed to achieve it is accorded both social and economic value. Conservation needs to be central to, rather than additional or opposed to, economic advancement for people living in the Outback. An economy is called for that protects and restores rather than depletes natural and social capital, and such benefit is mostly maintained locally.

Pastoralist David Pollock holds a photograph taken six years earlier in the same place, to illustrate the slow-but-sure regeneration of saltbush and other native vegetation since reducing sheep and cattle numbers on his Outback property, Wooleen Station, on the Murchison River, Western Australia. David has publicly called for the provision of stewardship payments to pastoralists so they can afford to destock and 'heal' the land.

There are existing programs and emerging opportunities for this in three main areas:

- conservation management services such as Indigenous ranger programs on national parks and IPAs and land-management services for pastoralists, miners and governments;
- climate change abatement, notably through better management of fires to reduce greenhouse gas emissions; and
- tourism and other nature-based industries (such as bush foods).

A sustainable economy, rather than green welfare, can be constructed – indeed is being constructed – from these foundations.

> There is an extremely high benefit-to-cost ratio of funding conservation in the Outback … it is much easier (and cheaper in the long run) to maintain healthy environments than to try to resuscitate them …

But public investment will still be required in some areas. There are compelling conservation and social reasons for much greater long-term public funding of conservation management in the Outback. The vast majority of public funding has always gone to the more populated and environmentally damaged parts of Australia (Robins and Dovers 2007), and there is an extremely high benefit-to-cost ratio of funding conservation in the Outback (Carwardine *et al.* 2006): it is much easier (and cheaper in the long run) to maintain healthy environments than to try to resuscitate them once they have lost their functionality and integrity.

Re-calibrating the development dreams to environmental reality

Intensified development that mines the Outback – for its soils, waters or minerals – can put at risk the much more precious commodity of the Outback itself, which relies on the intactness that intensive development destroys. Large-scale intensive agriculture and some forms of mining are not compatible with a sustainable future for the Outback. There is a place for both industries, but they need to be compatible with ongoing conservation and provide returns to local people. Any industrial activity should be done in a manner that does not compromise the values of the broader conservation and pastoral matrix. Maintaining what makes the Outback special needs to be fundamental to decisions about the extent and location of development.

The Outback provides resources that we can use, but it is bad policy and bad practice if those resources are squandered on non-sustainable and unprofitable enterprises.

> Large-scale intensive agriculture and some forms of mining are not compatible with a sustainable future for the Outback.

Governing fairly and effectively

At the national level, the Outback is treated in many uncomfortable and suboptimal ways, as a backyard, as an economic drain, as a place to impose policy and governance from afar (Walker *et al.* 2012). Instead, an Outback future must reflect and build from its ecological and social signatures and its governance must be based more intrinsically on its dispersed but integrated communities.

It is vital to note that these are not theoretical possibilities. Two major positive changes already occurring on Aboriginal-owned lands and on pastoral lands amply illustrate how development and conservation can progress very rapidly when the right social and economic conditions are present or provided.

As discussed in previous sections, a huge shift on Indigenous lands has been the increase in IPAs. In a 15-year period, 10% of the Outback – more than 500,000 km^2 – has gone into such areas on Aboriginal-owned lands. Associated with this has been the rise of formally organised Indigenous ranger organisations. There are now more than 750 ranger positions working for Aboriginal-run organisations through the Outback. This is probably the most rapid advance in conservation gains of any particular type in Australia. Country that has been long empty is now being progressively bought back to better ecological health through management of uncontrolled fires, feral animals and other threats. The work provides jobs and dollars for people living in remote areas who remain closely culturally attached to their country and who have few other employment options.

The other major shift in recent years is ongoing change in the on-ground use of pastoral leases. With decades of increasing costs and reduced real returns per unit of production, many pastoral leases can no longer support commercially viable grazing operations. For example, in Western Australia at least 30%, and possibly up to 60% of leases are no longer commercially viable as grazing enterprises (Novelly and Warburton 2012b, 2012a). As a consequence increasingly large numbers of pastoral leases are being taken up by owners who run non-pastoral enterprises – tourism, conservation, by mining companies, for living areas for Indigenous communities and as 'lifestyle' properties, bought by individuals for their ambience. This is most evident in districts where combinations of poor soils, erratic rainfall, and distance from markets make pastoralism marginal. For example, in the north-central Kimberley, north of the King Leopold Ranges, there are 16 large pastoral leases. Few of these, arguably only two, are now running a focused and viable pastoral operation. The bulk of the leases in the region are now run primarily or solely as tourism operations, explicitly for conservation, for Aboriginal communities as living areas, or as properties held for lifestyle reasons.

This trend has not been widely documented but is progressing rapidly in many districts. Unfortunately the changes in land use away from pastoralism rest on shaky legal foundations, as nearly all pastoral leases in all Outback states mandate that the lease be run solely or primarily as a pastoral operation. Changes away from pastoralism are at risk as different uses may be illegal, as they potentially transgress the Native Title Act 1993 and the legal rights of Traditional Owners. Some state regulatory agencies have turned a blind eye to enterprises not meeting lease conditions; others are seeking to reform the underlying mix of types of leasehold on offer.

However, if given the right legal footing and with due sign-off and permission from Indigenous landholders, such diversification of leasehold areas can provide major changes for social, economic and environmental good, bringing in new enterprises that are positive for land management in remote Australia.

These changes to create Indigenous Protected Areas and diversify pastoral leases are occurring over millions of square kilometres of the Outback. They are changing many Outback districts, with the potential to bring new dollars, jobs and better land management into country that was empty of people or had declining populations. Proactive and positive government policies will accelerate them further. They are providing major gains for much country and serve as a signpost for how relatively quickly positive change for people and the country can happen in remote Australia.

> With decades of increasing costs and reduced real returns per unit of production, many pastoral leases can no longer support commercially viable grazing operations.

9.4. Progressing the future: voices from the country

Since European settlement, the history of our treatment of, and relationships with, the Outback has been complex. Australians of European descent have a fascination for the Outback's grandeur, nature and distinctiveness. But they have also been slow to understand the way it works. Many prospects have been imposed on it, typically by governments, individuals and businesses that are not familiar with its constraints, its values, and its way of functioning.

In rare cases, there has been retrospective acknowledgement of the futility of development activity that lacked an appreciation of the Outback's character and constraints. One notable such exception is that of Nugget Coombs' acknowledgement in the 1960s of his involvement in agencies that planned, futilely, for the intensive development of northern Australia from the late 1940s:

Australians of European descent have a fascination for the Outback's grandeur, nature and distinctiveness. But they have also been slow to understand the way it works.

'Apart from its emphasis on research and experiment, the committee's work reflected the optimism of the time and the prevailing views, shared firmly by the committee itself, that growth was a good thing, that it could be achieved primarily by seeking to impose on the North a pattern of productive activity and a way of life essentially European in its origin and substantially European in its relevance. There is little evidence in the work of the committee, I am sorry to say, of a genuine understanding of, or an intuitive sympathy with, the climatic and territorial environments of the North. We were southerners, and Europeans, and never really got over the sense of being in a somewhat alien and hostile environment. ... There was an almost complete disregard for the character and potential of the natural flora and fauna of the North. ... There was nothing organic in the growth we planned for; it was fundamentally to be based on extractive and exploitative techniques. ... It is this lack, not merely in the work of the committee, but in the thinking about developments by me and my colleagues and the generation to which we belonged, which in retrospect is so disappointing' (Coombs 1977).

Instead, the Outback merits a future that is carefully crafted by and for Outback residents, that maintains and is based on the distinctive Outback values, and that is a meaningful part of the broader Australian journey. In this report, we seek to use the distinctive intrinsic ecological character of the Outback as a guide and base for, and a core element of, its future. We hope that this report adds to the emerging dialogue.

The Outback merits a future that is carefully crafted by and for Outback residents, that maintains and is based on the distinctive Outback values, and that is a meaningful part of the broader Australian journey.

Indigenous and non-indigenous people are working 'on country', blending western and traditional land management practices to achieve tangible outcomes for Outback lands. Pictured, Laura Land and Sea Ranger Roderick Doughboy and Lyndal Scobell from Cape York Natural Resource Management Ltd, overlooking the Kennedy Valley near Laura in Outback Queensland.

Appendix 1

Scientific names of plants and animals mentioned in report

We sought to introduce a cast of Outback plant and animal species in this account. For simplicity, we mentioned only common names in the text. The corresponding scientific names are listed here.

Common name used in text	Scientific name
Agile Wallaby	*Macropus agilis*
Anbinik	*Allosyncarpia ternata*
Annual Mission Grass	*Cenchrus pedicellatus*
Arnhem Leaf-nosed Bat	*Hipposideros inornatus*
Arnhem Rock-rat	*Zyzomys maini*
Arnhem Sheath-tailed Bat	*Taphozous kapalgensis*
Athel Pine	*Tamarix aphylla*
Australian Bustard	*Ardeotis australis*
Australian Snubfin Dolphin	*Orcaella heinsohni*
Banded Hare-wallaby	*Lagostrophus fasciatus*
Banded Stilt	*Cladorhynchus leucocephalus*
Barramundi	*Lates calcarifer*
Big-headed Ant	*Pheidole megacephala*
Bilby	*Macrotis lagotis*
Black-footed Rock-wallaby	*Petrogale lateralis*
Black-footed Tree-rat	*Mesembriomys gouldii*
Black Grass-wren	*Amytornis housei*
Black Kite	*Milvus migrans*
Black Wallaroo	*Macropus bernardus*
Bluebush	*Mairenia spp.*
Boab	*Adansonia gregorii*
Broad-cheeked Hopping-mouse	*Notomys robustus*
Broad-faced Potoroo	*Potorous platyops*
Boodie	*Bettongia lesueur*
Brush-tailed Phascogale	*Phascogale tapoatafa*

Common name used in text	Scientific name
Brush-tailed Rabbit-rat	*Conilurus penicillatus*
Budgerigar	*Melopsittacus undulatus*
Buffel Grass	*Cenchrus ciliaris (Pennisetum ciliare)*
Camel	*Camelus dromedarius*
Cane Toad	*Rhinella marina*
Cat (feral)	*Felis catus*
Cattle	*Bos taurus, Bos indicus*
Central Hare-wallaby	*Lagorchestes asomatus*
Central Rock-rat	*Zyzomys pedunculatus*
Cockatoo Grass	*Alloteropsis semialata*
Collett's Snake	*Pseudechis colletti*
Common Brush-tailed Possum	*Trichosurus vulpecula*
Common Planigale	*Planigale maculata*
Coolibah	*Eucalyptus coolabah*
Crescent Nailtail Wallaby	*Onychogalea lunata*
Darngarna Palm	*Livistona eastonii*
Darwin Stringybark	*Eucalyptus tetrodonta*
Darwin Woollybutt	*Eucalyptus miniata*
Desert Bandicoot	*Perameles eremiana*
Desert Bettong	*Bettongia anhydra*
Desert Oak	*Allocasuarina decaisneana*
Desert Rat-kangaroo	*Caloprymnus campestris*
Dingo	*Canis lupus dingo*
Donkey	*Equus asinus*
Dusky Hopping-mouse	*Notomys fuscus*

Common name used in text	Scientific name
Eastern Koel	*Eudynamys orientalis*
Echidna	*Tachyglossus aculeatus*
Emu	*Dromaius novaehollandiae*
Emu-wrens	*Stipiturus spp.*
Fawn Antechinus	*Antechinus bellus*
Flock Bronzewing Pigeon	*Phaps histrionica*
Frilled Lizard	*Chlamydosaurus kingii*
Gamba Grass	*Andropogon gayanus*
Ghost Gum	*Corymbia aparrerinja, C. papuana*
Giant Northern Termite	*Mastotermes darwiniensis*
Giant Reed	*Arundo donax*
Gidgee	*Acacia cambagei, Acacia georginae*
Goat	*Capra aegagrus hircus*
Golden Bandicoot	*Isoodon auratus*
Gouldian Finch	*Erythrura gouldiae*
Gould's Mouse	*Pseudomys gouldii*
Grey Wolf	*Canis lupus*
Gulf Snapping Turtle	*Elseya lavarackorum*
Grass-wrens	*Amytornis spp.*
Honeypot Ant	*Campanotus inflatus*
Horse	*Equus caballus*
House Mouse	*Mus domesticus*
Humpback Whale	*Megaptera novaeangliae*
Indo-Pacific Humpback Dolphin	*Sousa chinensis*
Itjaritjari	*Notoryctes typhlops*
Julia Creek Dunnart	*Sminthopsis douglasi*
Kakadu Dunnart	*Sminthopsis bindi*
Kakadu Pebble-mouse	*Pseudomys calabyi*
Kakarratul	*Notoryctes caurinus*

Common name used in text	Scientific name
Kimberley Rock-rat	*Zyzomys woodwardi*
Koala	*Phascolarctos cinereus*
Kowari	*Dasyuroides byrnei*
Lancewood	*Acacia shirleyi*
Largetooth Sawfish	*Pristis pristis*
Leichhardt's Grasshopper	*Petasida ephippigera*
Lesser Bilby	*Macrotis leucura*
Lesser Hairy-footed Dunnart	*Sminthopsis youngsoni*
Lesser Stick-nest Rat	*Leporillus apicalis*
Letter-winged Kite	*Elanus scriptus*
Little Red Flying-fox	*Pteropus scapulatus*
Loggerhead Turtle	*Caretta caretta*
Long-haired Rat	*Rattus villosissimus*
Long-tailed Hopping-mouse	*Notomys longicaudatus*
Magpie Goose	*Anseranas semipalmata*
Mala	*Lagorchestes hirsutus*
Malleefowl	*Leipoa ocellata*
Marsupial moles	*Notoryctes spp.*
Mesquite	*Prosopis spp.*
Mimosa	*Mimosa pigra*
Mitchell Grass	*Astrebla spp.*
monitors	*Varanus spp.*
Monjon	*Petrogale burbidgei*
Mosquito Fish	*Gambusia affinis (G. holbrooki)*
Mulga	*Acacia aneura*
Night Parrot	*Pezoporus occidentalis*
Ningauis	*Ningaui spp.*
Noogoora Burr	*Xanthium spp.*
Northern Brown Bandicoot	*Isoodon macrourus*

Common name used in text	Scientific name
Northern Brush-tailed Phascogale	*Phascogale pirata*
Northern Hopping-mouse	*Notomys aquilo*
Northern Quoll	*Dasyurus hallucatus*
Nullarbor Dwarf Bettong	*Bettongia pusilla*
Oenpelli Python	*Morelia oenpelliensis*
Olive Hymenachne	*Hymenachne amplexicaulis*
Pale Field-rat	*Rattus tunneyi*
Paperbark	*Melaleuca spp.*
Para Grass	*Urochloa mutica (Brachiaria mutica)*
Partridge Pigeon	*Geophaps smithii*
Perentie	*Varanus giganteus*
Perennial Mission Grass	*Cenchrus polystachios*
Physic Nut	*Jatropha curcas*
Pig	*Sus scrofa*
Pig-footed Bandicoot	*Chaeropus ecaudatus*
Plague Locust	*Chortoicetes terminifera*
Platypus	*Ornithorhynchus anatinus*
Prickly *Acacia*	*Vachellia nilotica*
Princess Parrot	*Polytelis alexandrae*
Quandong	*Santalum acuminatum*
Rabbit	*Oryctolagus cuniculus*
Rainbow Bee-eater	*Merops ornatus*
Red Fox	*Vulpes vulpes*
Red Kangaroo	*Macropus rufus*
River Red Gum	*Eucalyptus camaldulensis*
Rough-scaled Python	*Morelia carinata*
Rubber Vine	*Cryptostegia grandiflora*
Saltbush	*Atriplex spp.*
Saltwater Crocodile	*Crocodylus porosus*

Common name used in text	Scientific name
Sandalwood	*Santalum spicatum*
Sandhill Dunnart	*Sminthopsis psammophila*
Sandstone Antechinus	*Pseudantechinus bilarni*
Sand-swimmers	*Eremioscincus species*
Scaly-tailed Possum	*Wyulda squamicaudata*
Sheep	*Ovis aries*
Short-tailed Hopping-mouse	*Notomys amplus*
Silver Gull	*Chroicocephalus novaehollandiae*
Singing Bushlark	*Mirafra javanica*
Spangled Perch	*Leiopotherapon unicolor*
Spinifex	*Triodia spp.*
Squirrel Glider	*Petaurus norfolcensis*
Tasmanian Devil	*Sarcophilus harrisii*
Thorny Devil	*Moloch horridus*
Thylacine	*Thylacinus cynocephalus*
Tjakura	*Liopholis kintorei*
Tropical Short-tailed Mouse	*Leggadina lakedownensis*
Ward's Weed	*Carrichtera annua*
Warru	*Petrogale lateralis*
Water Buffalo	*Bubalus bubalis*
Weeping Myall	*Acacia pendula*
Western Chestnut Mouse	*Pseudomys nanus*
Western Pygmy Possum	*Cercartetus concinnus*
White-throated Grass-wren	*Amytornis woodwardi*
Woylie	*Bettongia penicillata*
Yellow Crazy Ant	*Anoplolepis gracilipes*
Yellow-footed Rock-wallaby	*Petrogale xanthopus*
Yellow-throated Miner	*Manorina flavigula*

Appendix 2

Full sources for maps and other diagrams

Figure	Source
1	Australian Statistical Geography Standard (ASGS): Volume 5 – Remoteness Structure, July 2011 (cat. no.1270.0.55.005). Accessed: 21/1/2014. (http://www.abs.gov.au/websitedbs/D3310114.nsf/home/remoteness+structure)
2	Based on Australian Government Department of the Environment data. Interim Biogeographic Regionalisation for Australia (IBRA), Version 7 (Regions). Accessed: 12/2/2014. (http://www.environment.gov.au/metadataexplorer)
3	http://www.daff.gov.au/ABARES/Pages/data/mcass/australian-national-map-layers.aspx
4	Based on Bureau of Rural Sciences data. VAST: Vegetation, Assets, States and Transitions. Version 2 – revised 2008. Accessed: 2/8/2013. (http://data.daff.gov.au/anrdl/metadata_files/pa_vast_g9abll0032008_11a.xml)
5	Based on Australian Government Department of the Environment data. Interim Biogeographic Regionalisation for Australia (IBRA), Version 7 (Regions). Accessed: 12/2/2014. (http://www.environment.gov.au/metadataexplorer/full_metadata.jsp?docId=%7B573FA186-1997-4F8B-BCF8-58B5876A156B%7D)
6	Wildlife Conservation Society (WCS), and Center for International Earth Science Information Network (CIESIN) Columbia University, 2005. Last of the Wild Project, Version 2, 2005 (LWP-2): Global Human Influence Index (HII) Dataset (Geographic). Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). Accessed 19/2/2014. (http://sedac.ciesin.columbia.edu/data/set/wildareas-v2-human-influence-index-geographic)
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8	Data provided by Luciana Porfirio and Brendan Mackey, with original publication in Woinarski *et al.* (2007)
9	Data provided by Luciana Porfirio and Brendan Mackey, with original publication in Woinarski *et al.* (2007), using VAST information (Bureau of Rural Sciences data. VAST: Vegetation, Assets, States and Transitions. Version 2 – revised 2008)
10	Mittermeier RA, Mittermeier CG, Brooks TM, Pilgrim JD, Konstant WR, da Fonseca GAB, Kormos C (2003) Wilderness and biodiversity conservation. *PNAS* 100, 10309-10313. Reproduced with permission: Copyright (2003) National Academy of Sciences, USA
11	Vörösmarty CJ, McIntyre PB, Gessner MO, Dudgeon D, Prusevich A, Green P, Glidden S, Bunn SE, Sullivan CA, Reidy Liermann C, Davies PM (2010) Global threats to human water security and river biodiversity. Nature 467, 555-561. Reprinted with permission from Macmillan Publishers Ltd: NATURE Copyright 2010

Figure	Source
12	National Catchment and Stream Environment Database version 1.1.5 (Stein *et al*. 2014) and the Australian Hydrological Geospatial Fabric (Geofabric) (http://www.bom.gov.au/water/geofabric/index.shtml)
13	From Geoscience Australia in cooperation with the States and the Northern Territory, from Heap *et al.* (2001) and http://audit.ea.gov.au/ANRA/coasts/docs/estuary_assessment/Est_Introduction.cfm
14	From Halpern BS, Walbridge S, Selkoe KA, Kappel CV, Micheli F, D'Agrosa C, Bruno JF, Casey KS, Ebert C, Fox HE, Fujita R, Heinemann D, Lenihan HS, Madin EMP, Perry MT, Selig ER, Spalding M, Steneck R, Watson R 2008, 'A Global Map of Human Impact on Marine Ecosystems', *Science* 319, 948–952. Reprinted with permission of the American Association for the Advancement of Science (AAAS)
15	http://www.worldwildlife.org/publications/terrestrial-ecoregions-of-the-world. Olson, D. M., Dinerstein, E., Wikramanayake, E. D., Burgess, N. D., Powell, G. V. N., Underwood, E. C., D'Amico, J. A., Itoua, I., Strand, H. E., Morrison, J. C., Loucks, C. J., Allnutt, T. F., Ricketts, T. H., Kura, Y., Lamoreux, J. F., Wettengel, W. W., Hedao, P., Kassem, K. R. 2001. Terrestrial ecoregions of the world: a new map of life on Earth. *Bioscience* 51, 933-938
16	From Holt BG, Lessard J-P, Borregaard MK, Fritz SA, Araújo MB, Dimitrov D, Fabre P-H, Graham CH, Graves GR, Jønsson KA, Nogués-Bravo D, Wang Z, Whittaker RJ, Fejdså J, Rahbek C *et al*. 2013, 'An update of Wallace's zoogeographic regions of the World', *Science* 339, 74–78. Reprinted with permission of the American Association for the Advancement of Science (AAAS)
17	From Freudenberger L, Hobson P, Schluck M, Kreft S, Vohland K, Sommer H, Reichle S, Nowicki C, Barthlott W, Ibisch PL 2013, 'Nature conservation: priority-setting needs a global change.' Biodiversity and Conservation 22, 1255–1281. With kind permission from Springer Science and Business Media. In the original paper, this figure is Figure 2f, where Fig. 2 EcoWise priority areas comprising indicators for biomass and structural heterogeneity (a) and biodiversity and complexity (b), EcoWise (c), SocioWise (d) and ClimateWise (e) conservation priority areas as well as the combination of all priority-setting criteria, the EcoSocioClimateWise priorities (f). Blue to yellow areas indicate low to high conservation priority. All data were normalized to a range of 0–100. Class breaks have been calculated with the Jenks Breaks algorithm.
18	Based on data from the Commonwealth of Australia (Geoscience Australia), Australian Bathymetry and Topography Grid, June 2009. Accessed: 22/01/2014. (http://data.gov.au/dataset/australian-bathymetry-and-topography-grid-june-2009)
19	Bureau of Meteorology. Mean monthly, seasonal and annual rainfall data (base climatological data sets). Accessed: 11/2/2014. (http://www.bom.gov.au/jsp/ncc/climate_averages/rainfall/index.jsp)
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21	Bureau of Meteorology. Mean monthly, seasonal and annual rainfall data (base climatological data sets). Accessed: 11/2/2014. (http://www.bom.gov.au/jsp/ncc/climate_averages/rainfall/index.jsp)
22	Bureau of Meteorology. Derived from http://www.bom.gov.au/climate/averages/tables/ca_nt_names.shtml and http://www.bom.gov.au/climate/averages/tables/ca_qld_names.shtml

Figure	Source
23	Bureau of Meteorology. Derived from http://www.bom.gov.au/climate/averages/tables/ca_nt_names.shtml
24	Modified from Smith MA, Ross J (2008) What happened at 1500-1000 cal. BP in Central Australia? Timing, impact and archaeological signatures. *The Holocene* 18, 379-388
25	Derived from the Atlas of Living Australia, (http://www.ala.org.au/). Note that this map displays only a random 2% of data
26	Based on data from Australian Government Department of the Environment. Australia – Present Major Vegetation Groups – NVIS Version 4.1 (Albers 100m analysis product), Accessed: 4/2/2014. (http://www.environment.gov.au/metadataexplorer/full_metadata.jsp?docId=%7B245434BF-95D1-4C3E-8104-EC4B2988782D%7D&loggedIn=false)
27	From González-Orozco CE, Laffan SW, Miller JT (2011) Spatial distribution of species richness and endemism of the genus *Acacia* in Australia. *Australian Journal of Botany* 59, 601-609. (http://www.publish.csiro.au/nid/65/paper/BT11112.htm). Copyright CSIRO 2011. Published by CSIRO Publishing, Collingwood, Victoria, Australia
28	Data from the Australian Natural Heritage Assessment Tool, which includes species' location records from Australian museums, Australian herbaria, Birds Australia, CSIRO, state and territory governments and other sources
29	Based on data from WA Landgate, modified by North Australian Fire Information service. Fire Frequency, 1K 1997–2010 Fire Frequency Image File. Accessed: 6/3/2014. (http://www.firenorth.org.au/nafi2/about/ausfrqdownload.htm)
30	Derived from data included in the Atlas of Living Australia
31	From Pavey CR, Nano CEM, Cole JR, McDonald PJ, Nunn P, Silcocks A, Clarke RH (2014) The breeding and foraging ecology and abundance of the Princess Parrot, Polytelis alexandrae, during a population irruption. *Emu* 114, 106-115. (http://www.publish.csiro.au/nid/96/paper/MU13050.htm). Copyright CSIRO 2014. Published by CSIRO Publishing, Collingwood, Victoria, Australia
32	From Klein C, Wilson KA, Watts M, Stein J, Berry S, Carwardine J, Stafford Smith M, Mackey B, Possingham H (2009) Incorporating ecological and evolutionary processes into continental-scale conservation planning. *Ecological Applications* 19, 206–217. Reproduced by permission of the Ecological Society of America.
33	From Woinarski JCZ, Ward S, Mahney T, Bradley J, Brennan K, Ziembicki M, Fisher A (2011) The mammal fauna of the Sir Edward Pellew island group, Northern Territory, Australia: refuge and death-trap. Wildlife Research 38, 307–322. (http://www.publish.csiro.au/paper/WR10184.htm). Copyright CSIRO 2011. Published by CSIRO Publishing, Collingwood, Victoria, Australia
34	Based on Data from Commonwealth of Australia (Bureau of Meteorology) 2012. Geofabric Hydrology Reporting Catchments - V2.1, Accessed: 19/11/2012 (http://www.bom.gov.au/water/geofabric/download.shtml)

Figure	Source
35	From Taylor G (1926) The frontiers of settlement in Australia. *Geographical Review* 16, 1-25
36	Data from Australian Government Department of Agriculture (ABARES). Land Use of Australia, Version 4, 2005–2006 (September 2010 release). Accessed: 14/3/2014. (http://data.daff.gov.au/anrdl/metadata_files/pa_luav4g9abl07811a00.xml)
37	Based on Australian Bureau of Statistics (ABS) data. ABS (2011). Basic Community Profile, Table B02: 'Selected Medians and Averages', Datapack. Accessed: 19/11/2013. (http://www.abs.gov.au/websitedbs/censushome.nsf/home/datapacks)
38	Reprinted fromMarinoni *et al*. 2012. O, Navarro Garcia J, Marvanek S, Prestwidge D, Clifford D, Laredo LA (2012) Development of a system to produce maps of agricultural profit on a continental scale: an example for Australia. *Agricultural Systems* 105, 33–45. Copyright, with permission from, Elsevier
39	Based on ABS data. ABS, (2011). Basic Community Profile, Table B01: 'Selected Person Characteristics by Sex', Datapack. Accessed: 19/11/2013. (http://www.abs.gov.au/websitedbs/censushome.nsf/home/datapacks)
40	Based on ABS data. ABS (2011). Basic Community Profile, Table B07: 'Indigenous Status by Age by Sex', Datapack. Accessed: 19/11/2013. (http://www.abs.gov.au/websitedbs/censushome.nsf/home/datapacks)
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42	From Stafford Smith M, McAllister RRJ (2008) Managing arid zone natural resources in Australia for spatial and temporal variability – an approach from first principles. *The Rangeland Journal* 30, 15-27. (http://www.publish.csiro.au/paper/RJ07052.htm). Copyright CSIRO 2008. Published by CSIRO Publishing, Collingwood, Victoria, Australia
43	Australian Institute of Aboriginal and Torres Strait Islander Studies (2005). http://arts.gov.au/sites/default/files/pdfs/nils-report-2005.pdf
44	Figures courtesy of Adam Liedloff, CSIRO Darwin
45	From Woinarski JCZ (2004) The forest fauna of the Northern Territory: knowledge, conservation and management. In 'Conservation of Australia's Forest Fauna'. (Ed. D Lunney) pp. 36-55. (Royal Zoological Society of New South Wales: Sydney)
46	Bureau of Meteorology. Rainfall and maximum temperature trend shapefiles 1950-2013

Figure	Source
47	Bureau of Meteorology. Rainfall and maximum temperature trend shapefiles 1950-2013
48	Based on data from Australian Government Department of Agriculture (ABARES). Dry Sheep Equivalent (DSE) per ha based on ABS 2010-2011 Agricultural Census data classified by SA2 regions, processed using ABARES methodology = 0.6*Marked lambs under 1 year + 1.7*Breeding ewes 1 year and over (merino + all other) + 1 * All other. Density values were joined to SA2 boundaries, and a raster was created where cells were given the value for the corresponding SA2. Accessed:11/6/2014 (downloaded as part of MCAS v3.1 sampledata http://daff.gov.au/ABARES/Pages/data/mcass/tool.aspx)
49	Based on data from Australian Government Department of Agriculture (ABARES). Dry Sheep Equivalent (DSE) per ha based on ABS 2010-2011 Agricultural Census data classified by SA2 regions, processed using ABARES methodology = 0.6*Marked lambs under 1 year + 1.7*Breeding ewes 1 year and over (merino + all other) + 1 * All other. Density values were joined to SA2 boundaries, and a raster was created where cells were given the value for the corresponding SA2. Accessed:11/6/2014 (downloaded as part of MCAS v3.1 sampledata http://daff.gov.au/ABARES/Pages/data/mcass/tool.aspx)
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51	Developed originally for this report
52	Derived from information supplied by the Australian Department of the Environment (http://www.environment.gov.au/indigenous/ipa/pubs/map.pdf) and ERIN IPA map
53	Derived from the Collaborative Australian Protected Areas Database reported up to 2012) (http://www.environment.gov.au/topics/land/nrs/science-maps-and-data/capad)
54	Collaborative Australian Protected Areas Database (http://www.environment.gov.au/topics/land/nrs/science-maps-and-data/capad)

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There is no place in the world quite like the Australian Outback. So, much of the way in which it should be managed needs to be developed intrinsically in response to its unique character and challenges.

The sun sets behind Pannawonica Hill and the Robe River in Western Australia's Pilbara region. Across much of the Outback, watercourses such as this ephemeral river, which is reduced to a series of permanent pools during the dry season, serve as important refugia for native animals and harbour distinctly different plant and animal communities.

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